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BUILDING ENERGY EQUIPMENT WORKSHOP

PROCEEDINGS

COMMITTEE ON SCIENCE AND TECHNOLOGY
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April 11, 1984

LETTER OF TRANSMITTAL

To All Members of the Committee on Science and Technology:

I am herewith transmitting the proceedings of the Building Energy Equipment Workshop sponsored by the Committee on Science and Technology at the Airlie House, December 5-7, 1983. The workshop was co-sponsored by the U.S. Department of Energy, the American Society of Heating, Refrigeration and Air Conditioning Engineers, the National Association of Home Builders Research Foundation and the American Institute of Architects. Its objectives were to examine the current status and future plans for research and development in improved efficiency and increased solar utilization for building energy equipment, and to make recommendations to improve the overall national effort in this area.

Fifty one participants, representing the building energy equipment and solar industries, their trade associations, the national laboratories, public interest groups, private sector research organizations and federal agencies, attended the workshop. I believe it was an important meeting, which could play a significant role in structuring the national research effort in energy efficient building equipment and active solar heating and cooling.

Any comments from Members of the Committee, other Members of Congress or private individuals and organizations will be welcome.

Sincerely,

DON FUQUA
Chairman

DF:Fba

PROCEEDINGS OF THE
BUILDING ENERGY EQUIPMENT WORKSHOP

Airlie House, Virginia
December 5-7, 1983

Sponsored by:

United States House of Representatives
Science and Technology Committee

American Society of Heating, Refrigerating, and
Air Conditioning Engineers

United States Department of Energy

National Association of Home Builders
Research Foundation

American Institute of Architects

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INTRODUCTION

The Building Energy Equipment workshop was held on December 5-7, 1983 at the Airlie House, Airlie, Virginia. It was sponsored by the House Science and Technology Committee, the U.S. Department of Energy, the American Society of Heating, Refrigeration and Air Conditioning Engineers, (ASHRAE) the National Association of Home Builders Research Foundation and the American Institute of Architects. The objectives of the workshop were to examine the current status and future plans for research and development in improved efficiency and increased solar utilization for building energy equipment and to make recommendations to improve the overall national effort in this area. The workshop considered the research programs of the U.S. Department of Energy, the Gas Research Institute, the Electric Power Research Institute, ASHRAE and others, and covered HVAC equipment, lighting, appliances, active solar heating and cooling, distribution equipment and integration of building equipment loads into overall building design.

At the workshop experts from the building energy equipment and solar industries, their trade associations, the national laboratories, public interest groups, private sector research organizations and federal agencies worked together to assess the state of the art in building equipment research and develop a statement of findings and recommendations. Participants were grouped into two panels -- one to consider

residential building equipment and one to deal with commercial buildings.

The reports of the two panels are presented below along with programmatic materials that were prepared by DOE, GRI, EPRI and ASHRAE for the opening plenary session. A list of participants follows.

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SUMMARY OF COMMERCIAL PANEL PROCEEDINGS
BUILDING ENERGY EQUIPMENT WORKSHOP
AIRLIE HOUSE, DECEMBER 5-7, 1983

Following the opening plenary session at which DOE, GRI, EPRI, and ASHRAE (see Appendices A1, A2, A3, B, C, D) presented their current and ongoing research programs and plans, the workshop participants were divided into two panels: one covering equipment for residential buildings and the other covering equipment for commercial buildings.

Reece Achenbach served as moderator for the commercial panel, assisted by J. Richard Wright. The leaders of four sub-panels were announced and assignments of other participants were made, resulting in the following groupings:

Heating, Cooling, and Distribution Systems and Controls

Gershon Meckler, Chairman
James Calm
Richard Denny
Richard Erth
Steven Freedman
Gerald Groff
Robert Minturn
Daniel Nall
John Woodworth

Lighting and Other Internal Loads

Maxine Savitz, Chairman
Sam Berman
Kenneth Cooper
Mary Ann Eichenberger
Don Felts
William Fisher
Robert Himmel

Multi-Building Equipment and Systems

Norman R. Taylor, Chairman
David Eakin
Thomas Northam
Lawrence Spielvogel

Active Solar Energy Systems

Alwin Newton, Chairman
Corbyn Rooks
Floyd Hayes
Michael Wahlig

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With the entire commercial panel meeting together and before the initial sub-panel meeting, the leaders of the four sub-panels and a few other participants made individual comments on the presentations given at the opening plenary session and other topics relevant to research and development programs on equipment for commercial buildings. These comments are summarized below and they are identified with the individuals making them.

Maxine Savitz pointed out that lighting is a major contributor to both peak loads and total energy use in commercial buildings. It has received much attention in recent years, and changing practices have resulted in considerable reduction in energy use. She emphasized that there was a continuing need for lighting with better performance and higher efficiency. She commented that the workplace is changing with the growing use of VDT's, keyboards, and robotics and lasers. Attention should be given to lighting needs that changes may cause. There is a need to integrate daylighting and artificial illumination effectively. Data are needed on the impact of lighting and other equipment on the well-being and performance of personnel.

Alwin Newton discussed the need for greater technical cooperation between the Department of Energy and industry. He stressed the need to learn what research and development on equipment is being performed by industry in order to reduce excessive duplication of effort between government and industry. He recommended that the results of government-contracted research should be reported in technical papers to a peer group in order to facilitate the dissemination of research information. He noted that the National Solar Demonstration Network program (NSDN) had made some manufacturers unhappy because it identified some active solar systems which performed poorly. He said that little or no analysis of the observed results had been performed,

but that there was much worthwhile information in the NSDN data if sufficient analysis is made.

Newton suggested that the U.S. should give more attention to international research and development. He said that non-azeotropic refrigerants used in heat pumps in Europe improve heating efficiency but lower cooling efficiency--which is unimportant in Europe. He also suggested that not enough attention is paid to research done in the past.

Gershon Meckler expressed the opinion that all the organizations reporting during the plenary session viewed problems in a parochial way. He stated that their research lacks integration, and explained that there is much analysis of components and little synthesis toward system performance. Meckler pointed out that architects, engineers, and builders integrate components into systems and that this process involves risks, e.g., fragmentation of research does not provide systems design integration. As an illustration, Fred Morse's earlier statement was cited that most flat plate solar collectors can attain a 50% efficiency, tested separately, but the best installed active solar systems are only 25% efficient, and the average of the systems tested delivered only 11% of the available solar energy to the load.

Norman Taylor said that information is available to design good multi-building distribution systems, but that failure of the equipment inside retrofitted buildings is sometimes the cause of the system failure. He placed strong emphasis on the need to improve the technology of building retrofit. He discussed the burning of trash to produce salable electricity or steam.

Taylor stated that there are complex problems in the distribution of energy to groups of buildings. Good controls are essential. He also said that the best tool for energy conservation is an occupant-sensitive control

system or meter. He pointed out that the production of envelope insulation, glazing, and other conservation materials require energy. Therefore, it is necessary to balance the energy required to manufacture conservation components against the energy saved by their use. Gershon Heckler echoed this observation by stating that even when operating energy is expensive, there is a limit to the expenditures that are economical for manufacturing more efficient equipment. Steven Freedman discussed the importance of determining life-cycle costs of energy conservation options over the life of the building.

Gerald Groff stated that a research and development program must be assessed with respect to the evaluation criteria. He said that the research objectives of GRI and EPRI are different from those of DOE and other parts of the private sector. He said that a research and development program must be evaluated on the basis of whether we are trying to save energy, money or natural resources.

Sam Berman asserted that two criteria should be used in evaluating research programs. Stated in the form of questions, these are:

- Does the research strengthen the industry?
- Is the research responsive to the needs of the industry and is there adequate communication between the researchers and industry?

James Calm stated that components research is not devoid of systems concerns.

Following this session of general comments, the members of the commercial panel assembled as sub-panels. These sub-panels evaluated the

current and near-term future research and development programs on equipment for commercial buildings that had been circulated to all participants before the workshop, and the sub-panels developed their own recommendations for programs that would result in improved efficiency and increased solar utilization for building energy equipment.

The four sub-panel reports were summarized briefly by the moderator in a plenary session of all workshop participants. These reports are included in the following pages. There were brief discussions of sub-panel reports by the full commercial panel which indicated general agreement with their recommendations and conclusions. Excerpts of a letter subsequently received from a panel member (See Addendum, page 25) details some dissenting views relative to the sub-panel reports. During the full panel discussions, it was generally agreed that the recommendations of two of the sub-panels regarding the appropriate role of government in research and development could be summarized as follows:

Appropriate Government Role:

- Government should not compete with industry in the development of commercial products.
- Government should not promulgate standards, but should participate in the development of standards using the national consensus process.
- Industry should participate with government in drafting building regulations.
- Government should avoid acceptance testing of products except for government use and for compliance with legal requirements.

REPORT OF THE SUB-PANEL ON HEATING, COOLING, DISTRIBUTION SYSTEMS AND CONTROLS

There is a need and place for the federal government to do commercial-sector research and development work. The role of the federal government in commercial and residential sector research and development is different. The sub-panel believes that there is a need for coordination between the federal government and industry, the design and build communities, and utilities. This coordination should be accomplished by establishing at the earliest practical time a federally-funded advisory committee or other advisory entity with representatives from each group to consult with and advise on projects that would have the most benefit to the nation. This would be an on-going activity with a monitoring and follow-up responsibility.

The sub-panel identified three phases of each research activity that should be addressed.

Phase One: Search for system-oriented goals that need to be met and identify and define problems that need to be solved. (This is an appropriate area for Government leadership; industry participation and consultation in this activity is important.)

Phase Two: Development of Solutions and Strategies. Identification, research and development on technical solutions to problems identified in Phase One. (Industry plays key role; Government may support industry activities.)

Phase Three: Commercial development. (Industry leads; government supports technological developments.)

RECOMMENDED BASIC TECHNOLOGY DEVELOPMENT
INDUSTRY--SHORTER TERM, LOWER RISK
GOVERNMENT-LONGER TERM, HIGHER RISK

TECHNOLOGY AREAS AND TOPICS

1. Technology Assessment and Planning

   - o Problem Definition Research (Through Multi-Party Team Programs)
   - o Collection and Analysis of Building System Performance Data
   - o International and Domestic Technology Monitoring and Technology Transfer
   - o Oversight Assessment (Through Multi-Party Efforts) of Government Programs.

2. Basic Environmental Control Processes (Air Quality, Comfort, Air-Distribution, Noise Control, etc.)

   - o Research to Investigate Appropriate Processes and Criteria for Occupant Health and Comfort.

3. Thermal Processes (Heat, Moisture Control, Building Dynamics)

- o Research on Improved Distribution System Configurations to Provide Better Humidity Control and Temperature Control, Including Load Matching, So As to Maximize Energy Use Efficiency

- o Research to Develop Improved Energy Transport Systems

- o Research on Optimal Dynamic Control Strategies to Maximize Comfort, Energy Use Efficiency.

4. Systems and Equipment

- o Research on Systems Technology for Heat Recovery and Load Management

- o Research on Advanced Heat Pump Technologies (Cycles, Equipment, Components)

- o Research on Alternate or Improved Refrigerants and Working Fluids (Basic Data, Property Measurements, etc.) to Increase Efficiency and Address Environmental Problems

- o Research on On-Site Co-Generation Technology

- o Development of Procedures to Validate R&D Results and Methodology.

The sub-panel identified research and development issues that they believe the government should and should not address:

Issues That Government Should Address (not in order of priority)

- Develop improved distribution system configurations to offer better temperature and humidity control including matching temperatures to load, so as to maximize the energy efficiency of the total system.
- Collect and analyze building system performance data.
- Develop improved indoor environmental control technology.
- Develop improved analytical tools for design synthesis.
- Develop technology for on-site co-generation systems.
- Develop advanced heat pump technology.
- Develop improved energy transport and storage technology.
- Develop dynamic building control strategies.
- Develop low cost sub-metering.
- Develop improved heat recovery technology.
- Develop improved non-CFC cooling/refrigeration working fluids.
- Develop advanced electronic control technologies.
- Perform research on properties and behavior of basic fluids.
- Develop procedures for evaluation of R&D results and methodology.
- Perform domestic and international technology assessment and transfer.
- Request industry assessment of government programs.

Issues that Government Should Not Address

- Product development
- Product testing
- Standards
- Regulation

REPORT OF LIGHTING SUB-PANEL

General Topics

I. Comments on Existing Programs

II. Research and Education Needs Not Presently Addressed

III. Issues Relevant for the User Community but Not Appropriate for a Federal Program.

I. Comments on Existing Programs

The sub-panel concurs that present research topics are responsive to the lighting community needs, to energy efficiency, and to promoting cooperative high risk programs with industry. The research support is very minimal, without duplication, but with several important areas not being addressed, which are discussed in Section II.

As an example of responsiveness to user needs, there is the long felt need for a replacement of the incandescent lamp which would maintain the point source, desirable color quality and the universal easy handling of the incandescent lamp, but which would be considerably more energy efficient and long lasting, have proportional power dimming, and be cost effective. Currently available screw-in fluorescent lamp products are useful, but do not duplicate the desired characteristics of incandescent lamps. Product development by manufacturers could be based on current joint government-industry efforts in engineering lamp science that is needed to understand basic phenomena.

II. Research and Education Needs Not Presently Addressed

1. Relevant research results in appropriate formats should be delivered to all levels of users and practitioners through improved use of existing avenues of communication and education. Federal programs should assure that project information is given to professional and trade societies. These groups should be exposed to the research at its initiation, and they should determine which research results should be conveyed to their members.

2. Field work on subjective responses to different and varying parameters of lighting quality should involve psychologists and human factor scientists with appropriate statistical analysis. Field measurements should be followed by evaluation. Work of Flynn and co-workers should be referenced to help define the program.

3. Field work determining behavioral and psychological responses to lighting parameters should build on laboratory measurements and involve medical personnel. Lighting parameters to be considered in this work and in the subjective response study described above should include light level, spectral distribution (including UV emissions), spatial distribution, flicker, and electromagnetic radiation.

4. Integration of the effects of lighting and day-lighting loads on HVAC systems and total building performances and design and the quantification of this interaction is needed to evaluate the overall effect of lighting technologies and strategies on total building energy consumption.

5. Actual performance of lighting systems and any other internal energy using equipment (controls, HVAC, distribution systems, etc.) as well as the energy loads caused by lighting and other equipment should be measured. Data collection should be followed by evaluation, interpretation and correction or change.

6. The level of effort to evaluate the impact of lighting and other equipment on health and productivity should be increased. This program should include complementary and parallel efforts to promote user confidence in the results. This area of research is important to ensure that new technologies are developed with an understanding of their impacts on human health and productivity.

III. Issues Relevant for the User Community, But Not Appropriate for a Federal Program

1. Development of products where basic research is not required, e.g., small building controls, lighting controls, specific lamps.

2. Promulgation of codes; development of design standards.

3. Timely updating of information on internal heat gains for equipment entering the market.

REPORT OF THE SOLAR SUB-PANEL

Introduction

This sub-panel generally endorses the existence of a federally-supported R&D program for active solar heating and cooling systems for commercial building applications. These active solar heating and cooling systems will complement, not replace, conservation measures. In many situations, energy conservation and passive solar approaches will continue to be adopted more readily than active solar systems and will thereby decrease space conditioning loads. However, they will not be able to displace entirely the need for active solar applications. Well-designed space conditioning systems will likely employ an integrated approach where energy conservation, passive solar, and active solar techniques will be used in combination.

This sub-panel report is divided into four sections. Section I contains general observations and recommendations concerning active solar space conditioning research. The following three sections contain recommendations on specific research tasks. The sub-panel decided to comment on the proposed solar R&D tasks in the DOE planning documents distributed prior to the workshop (Appendix A1, A2). Section II contains a brief recommendation on the Building Equipment Program Plan of the DOE Conservation Program. Section III contains extensive comments and recommendations on the November 1983 draft of the FY 1984 Annual Operating Plan of the DOE Active Solar Heating and Cooling Program.

After considering the DOE planning documents, the sub-panel recognized the need for additional R&D work on tasks not included in the DOE plans; these recommendations for additional R&D tasks are contained in Section IV.

I. General Comments

1. Large HVAC equipment firms would rather use their own funds than federal funds for development work that could lead to a commercial product within a 4- to 8-year period. A typical product development within such a firm takes 3 to 7 years.

   a. There is a corollary to this observation: Longer term research (i.e., longer than 8 years) is appropriate for federal support.

   b. It is questionable whether condensing heat exchanger R&D work qualifies for federal support under the time criteria.

   c. The sub-panel believes that R&D on advanced absorption-cycle heat pumps for heating and cooling is an example of an appropriate federally-supported effort since it is expected to require 8 or more years to commercialization.

2. The sub-panel agrees that strengthening U.S. industry is a worthwhile objective.

3. DOE should more widely publicize its major accomplishments and most useful reports. Examples of such reports are:

   a. Collector Test Standard (ASHRAE Standard 93-77 or the updated standard).

   b. Handbook of Experiences in the Design and Installation of Solar Heating and cooling Systems.

   c. Solar Collector Performance Manual.

   d. A passive solar heating analysis and design manual (to be published).

4. Industry advisors should be involved to a greater extent in DOE program planning and review.

5. The sub-panel recommends a wider distribution and peer review of DOE research results by requiring presentation and publication of research results at technical meetings and in journals.

II. Comments on DOE Building Equipment Program Plan

1. The proposed R&D on high efficiency thermally-driven heat pumps is appropriate for federal support. This work is similar to the solar program R&D on chiller and heat pump technologies.
2. The other elements of the Building Equipment Program Plan are not relevant to the commercial solar heating and cooling program, so recommendations on these program elements are not appropriate.

III. Comments on the FY 1984 Annual Operating Plan of the DOE Active Solar Heating and Cooling Program, November 1983 Draft

1. The sub-panel endorses the objectives of this DOE-proposed research, as expressed in the 1st paragraph on Page 13 of this Annual Operating Plan (AOP): "Research funded by the program is intended to achieve two objectives: (1) Significant cost reductions and/or increases in performance of active solar systems and components, and (2) significant improvements in long-term system performance, reliability, and durability".

2. Collector Research (page 15 of the AOP):

a. The R&D on low-cost, low temperature flat-plate collectors should be supported by DOE, but the develoment criteria should ensure a 20-year lifetime and toleration of stagnation temperatures encountered over that period.

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b. The high-temperature collector research is also appropriate for federal support. Cost, durability, and performance requirements should be explicitly included in the description of the research needed.

3. Absorption Chiller Research (page 16 of the AOP): This research on advanced absorption concepts capable of more than doubling the COP (from 0.7 at 185°F to 1.4 at 300°F) is appropriate for federal support if:

a. it can be shown (on the basis of systems analysis) to eventually lead to a cost-effective solar cooling and heating system; and if

b. the chillers and heat pumps can be controlled to produce good performance and continuous, non-cycling operation both under part-load and full-load conditions.

4. Rankine Chiller Research (pages 16 and 17 of the AOP): The sub-panel agrees with the low priority that DOE has assigned to this Rankine cooling technology, and agree with DOE's plans to limit the FY 1984 activities to the completion of testing of the solar/fossil-fueled superheated-steam Rankine system.

5. Desiccant Cooling Research (page 17 of the AOP):

a. The solid desiccant research, seeking to achieve COP values greater than 1.0 is appropriate for federal support if:

i. it can be shown (on the basis of systems analysis) to eventually lead to a cost-effective solar cooling and heating system; and if

ii. the desiccant systems can be controlled to produce good performance and continuous, non-cycling operation under both part-load and full-load conditions.

The sub-panel further recommends that, early in this R&D program, the research proceed to the fabrication and test of full-sized humidifier and heat exchange components, because of anticipated problems.

b. It recommends that low priority be assigned to research on liquid desiccant systems that employ open rooftop regenerators. If this work is pursued, it should include early study of maintenance problems.

c. It similarly recommends that any research on open-cycle systems using packed-tower regeneration should include early study of maintenance and desiccant vapor carryover problems.

6. Storage Research (pages 17 and 18 of the AOP, under the heading "Balance of Systems"): The sub-panel agrees with the DOE assessment that storage research does not have a high enough priority to justify federal support at this time.

7. Systems Analysis (pages 18 and 19 of the AOP): The sub-panel concurs that systems analysis work is appropriate for federal support. New concepts should be modeled and analyzed prior to proceeding. Care must be taken to model the new components as accurately as possible. The hardware R&D should be undertaken only if the system analysis shows promise that the hardware will eventually attain cost/performance goals.

8. Experimental Systems Testing (page 19 of the AOP, under the heading "Experimental Systems Research"): Although not stated explicitly, it is believed that this text in the AOP refers to systems-level testing at the Colorado State University (CSU) Solar Houses, which serve as systems test facilities. However, these houses are only appropriate for residential system testing, not for commercial-sized systems.

The sub-panel does not recommend that a commercial-sized system test facility be established. Rather, it is recommended that standard industry procedures be followed. This entails extensive laboratory testing of new systems, followed by selected instrumented field tests of prototype units.

9. Systems Effectiveness Research (pages 19 and 20 of the AOP, under the heading "Experimental Systems Research"): Systems effectiveness research (which is mainly concerned with system reliability and durability) is appropriate for federal involvement, because of the importance to the solar industry of the reliability and maintainability of installed solar systems.

10. Systems Performance Monitoring (page 21 of the AOP): Instrumenting a small number (say, 3 to 6) of field installations using the National Solar Data Network (NSDN) is appropriate for the federally-supported program, and could prove very useful, if the following steps are carried out: 1) the sites are fully instrumented; 2) the system performance is evaluated and compared with analytical calculations; 3) any deficiencies in performance are identified; 4) the system deficiencies are then corrected; and 5) the corrected system performance is then monitored and verified. Also, industry input should be used in site selections.

IV. Additional Comments

The sub-panel identified some research activities that should be carried out which are not contained in either of the DOE planning documents discussed in Sections II and III:

1. The NSDN existing data base on performances of solar systems in field installations should be analyzed as follows: A small industry advisory group should assist the NSDN contractor in identifying areas of data to be

explored and types of trends to look for and evaluate the results of the ensuing analysis. This analysis should identify any repeating deficiencies in system performance of field installations. The performance data may also contain clues to the reasons for poor performance, thereby leading to the formulation of corrective measures that will avoid similar problems in the future.

2. Design guidelines leading to better performance for hydronic solar systems should be developed, using federal funds to support the modest amount of experimental work required. Examples of such guidelines that would prove beneficial to the solar systems design community are:

   a. Development of design criteria for filling vent lines between collector array headers and storage tanks in drainback systems to reduce parasitic pumping power;

   b. Development of design criteria to equalize liquid flows among collectors in large collector arrays.

Information on design criteria resulting from these studies should be disseminated widely.

REPORT OF MULTI-BUILDING SUB-PANEL

Objective 1. A review of the current status and future plans of GRI, EPRI, ASHRAE, and the DOE programs on building and community systems and active solar heating and cooling by the sub-panel leader revealed that only the following projects or activities had potential for providing technical information for multi-building R&D needs:

GRI:
- o Gas-fired space conditioning systems
- o Commercial heat pumps and prime movers
- o Gas-fired and heat-driven dehumidification and cooling equipment and technology
- o Gas-fired cogeneration

ASHRAE: Considerable significance to various programs, particularly condensate line sizing research.

DOE Building and Community systems:

- o Heat distribution and integration
- o Thermally activated heat pumps

Objective 2. The sub-panel developed the following recommendations to improve the overall national effort for multi-building systems R&D:

Recommendation A. Develop and implement, under government leadership, a materials research program for working district energy distribution components, covering hardware replacement for new and upgraded systems. The goal should be the improvement of performance and effective life of multi-building systems consistent with effective cost control. Specific industry problem areas should be addressed, such as improving the materials performance of steam condensate return facilities.

Recommendation B. Study existing federal government inventory of sites using thermal energy distribution systems, investigating performance, cost, maintenance factors, energy conservation, and related data. Recommendations should be developed for plant improvements and establishment of criteria for retention/disposition decisions. The results of this study should be made available for guidance of the industry.

Recommendation C. Conduct studies and prepare reports on the occurrence and experiences involved in the phase-out of selected thermal energy distribution systems, including, but not limited to:

a. Factual examples
b. Regulatory effects
c. Public relations
d. Local government reaction
e. Financial considerations
f. Managerial considerations
g. Cause and effect relationships
h. Benefits
i. Post-phase-out problems.

Recommendation D. Study the energy consumption effect of statutory and regulatory requirements, such as OMB Circular A-76, in federal buildings, looking specifically at hours of system usage, maintenance, and effective operation.

ADDENDUM

The following four sections with appropriate headings are verbatim quotations from comments contained in a letter of Lawrence D. Spielvogel dated January 18, 1984, on the reports of the four sub-panels of the commercial equipment panel. They are comments received from Spielvogel when the original draft of the sub-panel's report was circulated to the panel participants for comment.

"Heating, Cooling, Distribution Systems and Controls

"It is my opinion that there is no need or justification for a Federally funded Advisory Committee. Federal funding is certainly not necessary. Where industry feels that a subject has sufficient significance, there is rarely a lack of ability to air their concerns. It is not very likely that an Advisory Committee, Federally funded or not, will be capable of adequately representing the breadth of concerns in the building industry, nor will it be possible to have the necessary technical expertise and experience to properly consider and evaluate the wide range of concerns experienced in the commercial building sector.

"A number of the issues that the Panel recommends that Government should address are product development related, which the Panel later says that Government should not address. Many other issues are so vague and non-specific, it is doubted that any reasonable level of effort could begin to provide the kinds of results that would end up being widely used at any time in the near future.

"Lighting

"The recommendations for needs not presently addressed have little to do with the subject of the Workshop, namely "building energy equipment". Rather, the recommendations concern themselves with communication, education, field work on responses, interactions, health and productivity, which has virtually nothing to do with building energy equipment research and development. While these subjects may be worth pursuing, they should be pursued in their own right, rather than being disguised as building energy equipment.

"Solar

"I find it interesting that solar equipment has been singled out, while no other type of equipment has. While many of the recommendations are valid for solar, they are just as valid, if not more so, for many other types of building equipment. Take heat pumps for example. Read through the report of the Solar Subpanel and substitute "efficient heat pumps" wherever "active solar" is mentioned and substitute "heat pump industry" for "solar industry" wherever it appears. Then select some other type of equipment instead of heat pumps and substitute it.

"What this indicates is that more research can be accomplished with any type of equipment, solar or conventional, and that it is quite probable that the money and effort spent on equipment other than solar will probably yield far greater benefits to the nation both short term and long term.

"With the inordinate amount of money and effort expended on solar during the last decade it is not very likely that additional money of almost any magnitude will produce benefits to the nation that begin to compare with those to be achieved by considering all types of equipment likely to be used in buildings.

"I do not agree with the additional comments concerning research not now planned by the Department of Energy. The National Solar Data Network has produced reams of evaluations and reports on exactly the subjects suggested. A careful reading of these reports will indicate that the deficiencies are numerous and highly varied. As a result, it is not very likely that simplified, generalized solutions can be developed, in much the same manner that it takes four volumes of the ASHRAE Handbook to present the kind of information necessary to have a successful, reliable and efficient heating and air conditioning system for the wide variety of buildings and situations encountered.

"Similarly, there exists reams of design guidelines for solar systems. Only when there is sufficient concern and demand for design information from the private sector will there be efforts made to gather, evaluate and publish design guidelines in the form desired by the industry and generally in the publications already used by the industry.

"Multi-Buildings

"None of the content of Objective 1 was discussed in the Subpanel deliberations. Therefore, it is fraudulent to imply that they represent the consensus of the Subpanel, much less that of the entire Panel. It would appear that all of the comments under Objective 1 are those of the Subpanel leader and were never shown to or discussed with the members of the Subpanel."

SUMMARY OF THE RESIDENTIAL PANEL PROCEEDINGS

Dr. Eugene Frankel served as moderator for the residential panel assisted by Steve Blegel of the National Institute for Building Sciences. The residential panel was divided into three subpanels, as follows:

A. Combustion-fired Equipment and Appliances

Lawrence Woodworth, Chairman

Frank Belles

Robert Thompson

Gerald Matthews

Frank Kensill

David Locklin

Walt Syniuta

John Millhone

Richard Caron

B. Electrical Equipment and Appliances

David Didion, Chairman

John Ryan

L.E. Chaump

Donald Ritgers

Steve Blegel

Hal Rhea

Arvo Lannus

Robert Thompson

C. Solar Equipment

Paul Kando, Chairman

Eugene Frankel

John Goldsmith

T. Kemper Brotherton

Patricia Harris

Susumu Karaki

Frank Kreith

John Mitchell

The residential panel met only to organize its subpanels and consider their reports. Therefore, there is no separate account of the proceedings of the full residential panel. The three subpanel reports, as modified by the full panel, are presented below.

A. COMBUSTION-FIRED EQUIPMENT AND APPLIANCES SUBPANEL

I. Problem Areas Identified.

A. Knowledge from retrofits of oil-fired equipment is not getting into the marketplace.

B. Advanced combustion-fired equipment is too expensive.

C. Home owners do not know about advanced combustion equipment.

D. Guidelines are needed for energy recovery devices.

E. Combustion-fired heat pumps require substantial development.

F. Condensing heat exchangers have suffered considerable common problems which need to be better understood.

G. Energy savings from solid-fuel combustion and spot-heating equipment have not been adequately assessed.

H. A better understanding of distribution and control systems is needed.

I. Integration of new technologies into the building structure needs better assessment.

II. Recommended Research Areas.

A. The integration of residential heating and cooling systems and building structures to optimize energy savings.

1. In warm-air systems.

2. In hydronic systems.

3. In heating system interaction with whole building energy performance.

B. Condensing Materials and Associated Issues.

1. Materials research.
2. Assess the benefits of condensing systems in the light of technical and institutional problems that have appeared to date.
3. Venting systems evaluation.
4. Assess the value of condensing heat exchangers as retrofit devices.
5. Evaluate impact of chlorides on corrosion in condensing systems.

C. Fuel Fired Heat Pumps.

1. Absorption systems.
2. Engine systems.

D. Technology Transfer in Combustion System Retrofits.

1. Research and documentation on the results of retrofits (demonstrated performance, cost effectiveness and safety).
2. Development of training materials.

E. Residential Solid Fuel Equipment.

1. Develop technology needed for coal/wood equipment efficiency ratings.
2. Fundamentals of solid fuels burning as basis for improved equipment.

B. ELECTRICAL EQUIPMENT AND APPLIANCES SUBPANEL

I. Criteria for public vs. private sector involvement.

DOE/EPRI	Manufacturers	DOE/EPRI Manufacturers
Support Fundamentals Research	Product Development	Applications

II. R&D needs and problem areas.

		DOE Involvement R	Industry D
A.	Heat Pump & A/C		
1.	Low temperature performance		×
2.	High connected load		×
3.	High performance compressors		×
4.	Improved performance heat transfer equipment		×
5.	Refrigerant/fluids research	×	
6.	Frosting phenomena	×	
	Defrosting phenomena		×
7.	Controls & demand modulation		×
8.	Transient performance (cyclic)	×	
9.	Humidity control (SHR criteria effective temperature)	×	

B.	Resistance Heating		
	1. Radiant vs. connective thermal comfort	x	
	2. Zoning: central vs. isolated (room)		x
C.	Distribution & Management System		
	1. Sensible heat storage (cool)		x
	2. Latent heat storage - residential cool storage	x	
	3. Integrated home energy management		x
	4. Switches/registers/dampers, etc.		x
	5. Thermal modeling (multi-zone)	x	
D.	Phase Change		
	1. Desiccant materials research	x	
	2. Evaporative cooling systems		x

		DOE Involvement	Industry	
		R	D	
E.	Low Voltage D.C. Equipment			
	1. Photovoltaic source		x)	
	2. Fuel cell source		x)	ECM
	3. Thermoelectric source		x)	R&D
	4. Piezo electric motors		x)	
F.	Advanced Cycles			
	1. Thermodynamic			
	- Reverse Stirling			
	- New cycles	x		
	2. Magnetic/thermoelectric	x (assess)		

3. Hybrids

III. Recommendations for DOE Research.

*A. Refrigerant/fluids research, e.g. nonazeotropic materials.

*B. Frosting/defrosting phenomena: understanding phenonema, not developing controls.

*C. Thermodynamic cycles (new cycles).

D. Transient performance.

E. Desiccant materials.

F. Radiant/convective resistance heating.

G. Latent heat storage.

H. Appliance insulation materials. Less important than the rest.

I. Magnetic/thermoelectric.

J. Humidity control.

C. SOLAR EQUIPMENT SUBPANEL

I. Recommended Research and Development Activities*.

A. Develop cost-effective combined active heating, hot water and desiccant cooling system utilizing low cost medium temperature (130°-160°F) collector.

B. Develop low cost collectors for 130°-160°F that can be used in a desiccant cooling system.

C. Carry out systems integration research.

1. Packaging systems.

2. Integration with conventional heating and cooling systems.

3. Integration with buildings as systems - including passive and energy efficient design strategies and accounting for convective and radiative transfer mechanisms.

4. Develop user-oriented performance guidelines for integrated systems.

D. Research to understand and improve system and component reliability.

E. Develop a mechanism to formally involve industry - buildings, marketing and manufacturing sectors - in planning, implementing and reviewing research activities.

F. Develop realistic cost and performance goals to guide research.

G. Develop a mechanism to formally involve industry in the development and dissemination of useful and understandable information on emerging solar technologies.

H. Develop packaged, cost effective, easy to install solar domestic hot water systems.

The full residential panel questioned recommendation A on the grounds that DOE should probably not be involved in product-related research. It also questioned recommendation C, on the issue of whether systems integration research is useful in the absence of cost effective components. Recommendation H met similar skepticism on the grounds that the existing solar hot water industry, especially the large corporate manufacturers, would have developed packaged, low-cost systems if it were possible. The panel questioned whether DOE has any special knowledge or competence to carry out the proposed task. In general, many members of the full residential panel believe that the proper DOE role is to carry out fundamental research in areas such as materials or innovative concepts that could lead to technological breakthroughs which could substantially reduce costs or improve performance.

* The solar subpanel did not specify whether the recommended research should be carried out by government-sponsored programs or industry. However, given the precarious state of the solar industry, the subpanel felt that DOE would be the most likely source of research and development funding.

NOJC COMMENTS ON JANUARY 6, 1984 DRAFT
BUILDING EQUIPMENT WORKSHOP -
RESIDENTIAL PANEL REPORT PREPARED BY THE
HOUSE SCIENCE AND TECHNOLOGY COMMITTEE
AND RESULTING FROM THE WORKSHOP HELD AT THE AIRLIE HOUSE
IN VIRGINIA, DECEMBER 5-7, 1983

NOJC views the workshop and finalized report as very important activities of the House Science and Technology Committee. As stated in the letter of invitation from Chairman Fuqua:

> "Its objectives are to examine the current status and future plans for research and development ..."

In addition, the staff memorandum to participants in the workshop explained that the purpose of the conference was to set the national R&D agenda which the Committee will pursue in the authorization/appropriation process for the fiscal year 1985 budget.

NOJC has reviewed the draft residential panel report and has several observations and comments to make on the draft report.

From an overall perspective, NOJC believes that the recommendations/directions this draft report specifies and implies represent a strong R&D agenda that meshes well with the existing gas and electric utility infrastructure. We agree that it is appropriate to interface and coordinate with the utility industries. However, we are concerned that the structural arrangement ignores the quite different conditions that exist in the oil industry. This will result in depriving millions of fuel oil consumers, who have been bearing the highest energy prices since 1973, of the benefits of the present activities of the Committee. There are important areas where R&D in fuel oil equipment and combustion is necessary and cannot be ignored.

The natural gas and electric utility industries have elaborate, well-funded research facilities (EPRI & GRI) which provide them with applied research. This research is funded under the monopoly umbrella provided by government authority from the state public service commissions. Each utility passes through a specified cost to its rate base, generally without its consumers knowing about this surcharge on their bills. Thus, utilities are receiving complete governmental authority to fund their existing sophisticated research activities either through federally appropriated funding or institutionally approved cost pass throughs.

What utilities need, and are getting if the draft report recommendations are followed, is for the government to also pick up the cost of funding expensive long range basic research. The utilities then will have a complete basic to applied, research and development program fully paid for and approved by government authority. We read this report to indicate that government will play no role in oil consumers' R&D needs.

The competitive oil industry does not have exclusive territories, or any means to apply R&D costs equitably to all customers. The manufacturers of oil products -- the refineries -- do not support any R&D activities on

behalf of end users or equipment manufacturers. Individual marketers, unlike utilities, compete among themselves and cannot set a higher price to the consumer in order to finance R&D activities. Indeed, marketers are "eating" many of the increased costs passed through to them by their supplier.

NOJC believes that the House Committee on Science and Technology must not, as the draft report appears to do, view the R&D interests of utilities and private sector marketers as if they are similar and subject to the same R&D needs. They are not. Therefore, oil heat needs should not be subjected to the same assessment and criteria as the utility companies, particularly in the critical area of R&D. Research and development represents the lifeblood of the future. NOJC believes that government must play a role in areas of basic and applied fuel oil equipment R&D. The utility sector is already receiving government institutional authorization for their research needs. Oil consumers have borne the highest prices for the longest period of all fuels, and they deserve to benefit from government R&D areas of increased efficiency and performance.

Recommendations

The millions of fuel oil consumers served by the marketers have different needs than utility-oriented R&D. These needs are completely ignored by the draft report and we urge the Committee to recognize these needs and provide the necessary R&D funds.

DOE/CE-0060 D-R-A-F-T

APPENDIX A1

FY 1984

ANNUAL OPERATING PLAN

ACTIVE SOLAR HEATING & COOLING PROGRAM

DRAFT

NOVEMBER 1983

FY 1984
ANNUAL OPERATING PLAN
ACTIVE SOLAR HEATING & COOLING PROGRAM

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*This information is currently under development.

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ANNUAL OPERATING PLAN
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*This information is currently under development.

I. INTRODUCTION AND OVERVIEW

I.1 Purpose of FY 1984 Annual Operating Plan

This document serves as the primary instrument for managing the FY 1984 Active Solar Heating and Cooling program. It contains information regarding program structure, project schedules and milestones, and procurement plans for projects initiated in FY 1984, or earlier. The document will be revised as Field Task Agreements are negotiated with the National Labs, and as contracts are awarded.

I.2 Rationale for Federal Programs

The solar heating and cooling industry is still in its infancy. A relatively small number of large manufacturers supply copper and aluminum absorber plates, tempered glass covers and fiberglass insulation which are assembled into collectors by more than 250 manufacturers. These together with other components are incorporated into active solar hot water and space heating systems by several thousand small suppliers around the country. The installers tend to be residential-scale contractors who derive less than 25% of their business revenues from active solar installations.

Building space conditioning and hot water heating account for more than one third of the nation's total energy consumption and therefore represents a significant target for energy displacement. Since solar energy can be efficiently captured at moderate to low thermodynamic potential, it is ideal for use in space conditioning and hot water heating.

The development in solar technology for active space conditioning and hot water systems and the introduction of solar systems into the marketplace has demonstrated the viability of this approach and, more importantly, its application to a diverse market both climatically and by user type.

Active solar installations in 1981 (the most recent year for which accurate installation data is available) were predominantly in the single family housing sector (95% of installations and 87% of gross sales). About 70% of total installations were for space heating or combined space and water heating. There were very few installations involving active solar cooling.

The potential market for active solar technologies remains strong. Numerous surveys indicate that the majority of consumers believe that solar energy will represent a significant part of America's energy mix in the relatively near future. However, these percentages decline significantly in response to questions concerning general likelihood of purchase and still further when consumers are exposed to the economics of systems that are currently available. In response to limited demand, only two percent of America's homebuilders offer solar hot water systems as a standard feature.

Furthermore, the building construction industry itself is fragmented and decentralized. It consists of more than 200,000 small to medium sized firms serving local market areas. The industry is conservative and risk-averse; it is reluctant to use systems that increase the initial cost of a building, no matter how cost-effective the investment is, unless there is proven consumer demand.

Traditionally, new products are introduced by manufacturers with the capital and distribution network to back these innovations until they become accepted. The many small manufacturers comprising the solar industry are limited in their ability to fulfill this role. The thousands of small suppliers and installers do not have the capital or product credibility to provide a sustained, national presence for their systems.

All these factors led to the Solar Energy Panel of DOE's Energy Research Advisory Board to recommend that DOE continue to provide Federal support to R&D activities that enhance the development of the scientific and technical basis for an increasing, cost-effective use of the solar resource.

The information and results generated by the DOE active solar program can also assist the U.S. solar industry to effectively market abroad. It is clear that a huge potential market exists world-wide for solar energy systems and a number of countries, such as Germany, France, and Japan, have established major efforts directed at marketing solar equipment and systems overseas. R&D aimed at enabling the solar industry to produce high quality and cost effective systems will help the U.S. maintain a competitive stance in the export market.

I.3 Program Priorities for FY 1984

Priority is given to research and development of new collector designs and improved solar cooling concepts to achieve breakthroughs in performance or significant cost reductions. If this can be done, active solar systems can compete in a wider range of building applications than is possible today and their adoption by the building industry will be enhanced. In addition, the program directs resources to research and other activities needed in the near term that the solar, construction or HVAC industries are not equipped or not likely to undertake, such as performance monitoring of existing systems and efforts to improve the reliability and durability of active solar system components and materials, and research to assist industry in developing consensus-based testing and performance standards.

I.4 Multiyear Perspective

The Active Heating and Cooling Program has sponsored R&D for almost a decade and in so doing has established an extensive base of fundamental knowledge and understanding of some of the basic technologies for building space conditioning systems using solar energy. This information has been accumulated by supporting research in universities, laboratories and industry in analytical analysis, proof of concept experimentation and in-situ data gathering and interpretation. These activities have not only established the clear conclusion that active heating and cooling is a viable technical option but has also helped in identifying important research tasks that must be addressed before cost competitiveness can be achieved and therefore commercial viability established.

The Program Plan is structured to define overall program objectives, goals and strategies to support the research and development of several approaches for solar space conditioning and hot water systems. It is assumed that all the approaches will employ conservation and passive techniques as appropriate with the active solar system added on the basis of incremental cost. The technologies have been defined in prior DOE research activities with input from industry, universities, laboratories, professional organizations and independent consultants. In addition, special planning sessions and topical reviews were conducted during FY83 in preparation of the program plan.

The program research activities are defined in the plan. These activities include research on materials, components, system analysis and system experimentation which includes testing, performance monitoring and reliability assessment. The development of the program and its various elements are designed to take advantage of the industry/government partnership that has already achieved notable gains.

The program balances the long term goals with the need of short term requirements of continued industry and research organizations participation in current problem areas. For example, although the open cycle absorption will be supported as part of high risk research, the closed cycle absorption heat pump research will be continued. Major emphasis will nevertheless be placed on approaches which appear to have high probability of success to achieve cost/performance goals.

A. Technology Goals

The technology goals for active solar heating and cooling, like the program itself, have evolved with advancements in the state of the technology and changes in the cost of competing space conditioning systems. Current technology goals or objectives are stated in terms of performance/cost ratios, and durability indicators for specific kinds of systems, rather than in terms of market share.

A systematic methodology has been developed to establish cost/performance goals of systems and components. This approach helps define and evaluate research and development activities with respect to their potential for contributing to the development of one or more active solar systems that have a high potential for cost-competitiveness with conventional systems.

The cost goals are calculated using simple payback periods of 7 years for residential systems and 5 years for commercial systems. Each solar system is assessed relative to its cost goal by estimating the cost of the system and its competing conventional system. The identified systems are then ranked primarily on the basis of the ratio of estimated cost to cost goal for the "incremental" solar system.

B. Government Program Objectives

The DOE Active Solar Heating and Cooling Program has two basic objectives for its research:

- To achieve significant cost reductions and/or increases in peformance of active solar components and systems. Analyses indicate that solar space conditioning systems must achieve dramatic cost reductions or increases in performance on the order of a factor of two to four over the performance/cost ratio of today's active solar systems.

- To achieve significant improvements in long-term active solar system performance, reliability, and durability. While there have been steady improvements in this area, there remains a significant gap between predicted and measured system performance and reliability.

C. Operating Strategy

The program seeks to advance the state-of-the-art of active solar. The operating strategy is to support critical research and activities

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that cannot or will not be developed by the solar industry, but which will be required if active solar heating and cooling is to become a competitive technology. The key to this strategy is the identification of appropriate research through a planning process that involves universities and industry, as well as DOE and government laboratories.

The goals discussed previously are the primary targets used for selecting long-term research tasks of the Program. Although the cost goals are based on a set of complex assumptions which will be affected be economic considerations, fuel availability and unforeseen circumstances, they represent the best estimates currently.

To meet the objectives/goals of this program, the following guidelines are imperative:

- o Support technology options which can be integrated with existing and future systems.

- o Support those R&D developments which have high probability of technical success and which have moderate to high probability of contributing to energy savings.

- o Support options that have analytical evidence and/or laboratory evidence of superior performance or are significantly innovative to justify introductory research.

The strategy, subject to the above guidelines, is to provide Government support for those R&D activities which industry is not capable of supporting. Program tasks will be cognizant of the following:

- o industry/government partnership;

- o increased university and small business participation;

- cooperative efforts with industry supported organizations
- competitive RFP's as well as solicitations for addressing specific issues.

II. TECHNOLOGY STATUS

This section summarizes the current environment in which the FY 1984 activities of the Program were planned. Factors included are the status of the solar industry, the market and of technical developments. Recent accomplishments in advancing the technology are summarized.

II.1 State-of-the Art

The state-of-the-art for different active solar design systems reflects the differences in their historical development, technical complexity and system cost. Solar water heating systems are available at costs that range from $2,000 - $4,000, and offer potential savings from 40% - 70% in annual hot water heating bills. Packaging of major component subassemblies exists, along with reasonably good information on system installation and acceptable sizing/performance estimating techniques. The primary improvements required for these systems are cost reductions in the major cost components such as collectors.

Active solar space heating systems, of both air and liquid design, have been widely demonstrated in the field with varying degrees of success. Properly designed and installed systems have been shown to work well. However, active solar heating systems still suffer from high first costs ($8,000 - $20,000 installed cost for potential savings of 30% - 70% of annual heating bills), uncertain performance, and questionable long-term reliability. Many of the performance and reliability problems experienced to date can be traced back to design and installation practices rather than to equipment limitations. The development of factory-specified space heating packages should help to reduce some of these problems. However, significant cost reductions and, to a somewhat lesser extent, performance improvements will be required to meet the performance/cost ratios of conventional space heating systems.

In active solar cooling a number of different concepts involving solar driven, or "thermally activated" absorption, Rankine, desiccant, and hybrid configurations are still in the research and development stage. Previous work has focused on chiller development rather than on the cooling system as a whole. Absorption and Rankine solar cooling prototypes are the most advanced of these concepts. They have demonstrated reasonable levels of performance in the laboratory, but have fared worse in field test situations. They are only available on a custom order basis and at very high cost (e.g., $25,000 - $40,000 for a residential-sized absorption system including collectors, storage, etc.). Solar drive desiccant systems have shown promise in the laboratory, but await further research before they can become competitive. Significant increases in performance and reductions in cost are required before any of these cooling approaches can meet their required performance/cost goal.

For commercial buildings, solar-powered Rankine cycle turbines and engines are under intensive study as power sources for vapor compression refrigeration equipment. The U.S. and Saudi Arabia have joined forces under the SOLERAS program to build and test a number of systems large enough to air condition small commercial buildings. The test phase was started at the end of summary 1981 in Arizona where the climate is similar to that in Saudi Arabia.

II.2 FY 1983 Program Accomplishments

In FY 1983, the Department's efforts resulted in significant advances in several areas. In collector research, preliminary testing of the low-cost thin film polymeric collector indicated the need for additional design and materials research. This collector is very lightweight (16 lbs. for a 4' x 8' panel), and is intended for use in applications requiring temperatures up to 180°F (primarily solar heating). Early estimates indicate that the collector could be fabricated and installed at a cost of $8 per square foot as compared with $15 to $25 per square foot for collectors of comparable performance. A Program Research and Development Announcement (PRDA) was issued and awards made to both continue development of the thin film polymeric collector and transfer the technology to industry.

In the area of high performance collectors (>200°F) high performance coatings and materials, research has allowed a 50% improvement in the efficiency of the compound parabolic concentrating collector (CPC) at 280°F, while an advanced CPC under development offers a potential operating temperature (average) of 375°F at efficiencies over 60%.

In active solar cooling, several new concepts explored in FY 1983 appear to hold promise for dramatic performance improvements. An advanced regenerative air cooled absorption chiller is entering the preliminary test stages of a development program that promises potentially COP's of 1.3 - 1.5 at input temperatures of 300°F. This is a significant improvement over the current generation of solar absorption systems, which currently perform at COP's of .6 - .8 at 200°F inputs.

Testing of advanced solid desiccant dehumidifier designs using a spiral-wound dehumidifier configuration have also shown that COP's greater than 1.0 are attainable. Previous designs have demonstrated COP's in the range of only .5 - .6. These performance improvements translate into substantial reductions in required collector array areas for cooling components. Considering that the collector costs are between 20 and 40 percent of total system costs, this should result in substantial system cost reductions.

In solar heating research and development, the Department is in the preliminary test phase of several advanced solar heating systems configurations. These systems will incorporate innovative design and packaging concepts to reduce total system collectors and composite storage tanks, building integrated air collectors and modular storage, and use of a ground coupled heat pump in the system.

In addition, the Department supported activities designed to provide the solar industry with the information needed to develop improved products and designs. The National Solar Data Network (NSDN) continued to provide technical data on system performance, reliability, and maintainability from

instrumented sites throughout the U.S. Comparative reports on system performance were prepared, and that information made available to government, industrial, and university researchers.

FY 1983 also saw the completion of 647 solar installations built by federal agencies funded by the Department's Solar in Federal Buildings Program. Information from these applications will provide baseline data by which to gauge improvements in future designs, as well as basic information on systems performance and operation to aid engineers and designers.

Also in 1983, the Department continued to support the development of consensus-based standardized test and measurement procedures for the active solar heating and cooling industry, including test methods for determining degradation of absorptive coatings and nonglass coverplate materials; and side-by-side tests and experiments to validate the solar water heating standard (ASHRAE 95P).

II.3 Research Needs and Problems

Active solar systems are technically feasible in a large variety of hot water, space heating and cooling applications. However, the performance, durability, reliability, and cost-effectiveness necessary for their widespread use does not yet exist. Greater market acceptance of active solar technologies requires that the following be achieved:

- Significant cost reductions and/or increases in performance. Analyses show that the performance to cost ratio of active space conditioning systems must be significantly improved. In particular, major components such as solar collectors and energy conversion equipment, must achieve dramatic cost reductions or performance improvements. The performance/cost ratio of current systems must be increased by a factor of 2 to 4 times. This in turn will require:

  - The development of materials with improved thermal, chemical, optical and structural performance

- The development of lower cost materials, designs, and methods of assembly and installation

- The development of more efficient methods of solar collection, storage, and energy conversion.

- Significant improvements in long-term system performance, reliability, and durability. While systems installed over the past several years have met with a fair measure of technical success, there remains a significant gap between predicted system performance and reliability, and measured results. Bridging this gap to obtain systems capable of achieving 20-year service lives at sustained levels of performance will require:

  - Increasing system performance through improvements in the integration of standard components and the control of current and advanced systems

  - An improved understanding of the key factors that influence component and system performance

  - The development and application of effective performance measures, measurement techniques, and evaluation methods.

III. FY 1984 PROGRAM DESCRIPTION

In FY 1984, the program consists of two program elements. Activities within the Materials and Component Research Program Element are directed toward meeting the long-range competitive performance/cost requirements for active solar systems. The focus is on research to develop new or improved materials, components and sub-systems for active solar heating and cooling systems. The Systems Research Program Element is directed toward activities having the more immediate objective of improving performance, reliability, and durability of current state-of-the-art systems. The purpose is to provide industry with system performance data and analysis tools necessary to support the technology base needed for active solar technology development. In this area, the focus is on collecting, analyzing and disseminating thermal performance, reliability, and durability data from National Solar Data Network (NSDN) sites, and from experimental prototype systems developed under the program. Exhibit 1 depicts the organizational breakdown of the program.

III.1 Program Goals and Objectives

The FY 1984 Annual Operating Plan presents a program to advance the state-of-the-art of active solar heating and cooling technology. The goal is to bring efficient, economically competitive, and environmentally acceptable solar technology options into the marketplace by developing the technology base for subsequent private sector initiatives.

The program strategy is to support critical research that cannot or will not be undertaken by the solar industry, but which will be required if active solar heating and cooling is to become a competitive technology.

Research funded by the program is intended to achieve two objectives: (1) significant cost reductions and/or increases in performance of active solar systems and components, and (2) significant improvements in long-term system performance, reliability, and durability.

The FY 84 program is based upon the results of a planning exercise involving industry representatives, university researchers, the national laboratories and DOE program staff. These groups developed a set of research activities within the context of Administration policy, recommendations made by the ERAB Solar Panel, and guidance contained in House and Senate appropriations committee reports. Priority is given to long-term, high-risk research. At the same time, an attempt is made to strike a balance with shorter term research needed by the solar industry.

Long-term research activities focus on unique materials and fabrication problems of medium and high temperatures collectors, advanced absorption and Rankine chillers, and desiccant dehumidifiers for solar driven cooling applications. In the shorter term, emphasis is placed upon collection and analysis of system performance data and its application to reliability and durability research. In both areas, technology transfer mechanisms will be developed and implemented through various industry and research groups.

III.2 Program Structure

The following outlines FY 1984 activities to address these needs. Exhibit 1 depicts the Active Solar Heating and Cooling Program and the program elements. Specific projects and activity milestones within these elements are described in Exhibit 9.

III.3 Program Elements/Planned Accomplishments

A. Materials & Component Research

The focus of this program element is on research and development of new or improved components for active solar systems, and to establish basic information on the thermal, physical, optical and structural properties of new and improved materials and such systems. Research activities in this program element are grouped by major component. Proposed research activities are presented in the context of significant accomplishments that have been recently achieved.

1. Collectors

The FY 84 effort focuses on the development and application of improved materials for use in lower temperature flat plate collectors (useful operating temperatures up to 180°F) for hot water, space heating and desiccant cooling applications, and higher temperature collectors (useful operating temperatures up to 350°F) for absorption and Rankine cooling applications. Previous research in medium temperature collectors has identified the use of thin-film polymeric materials and laminates for glazing, enclosure, and absorber applications as particularly promising for reducing collector costs and meeting performance/cost objectives. Designs, employing a thin film laminated absorber appears particularly attractive. In FY 1984, research will continue on this type of collector with emphasis on identifying suitable adhesion methods to maintain absorber integrity under continuous operation, and on a search for more optimal materials. Complementing this work will be applied research on candidate polymer materials to determine their response to combined thermal, optical, and mechanical stresses over long periods, and the development of generic methods to both predict and mitigate the impacts of these stresses in the short-term.

High temperature collector research is aimed at improving the efficiency of evacuated tube collectors on the order of 50% at 275°F operating temperatures. Previous research has resulted in the development of various air and liquid models, including the compound parabolic concentrating (CPC) collector. Recent activities have resulted in completion of the theoretical analysis of CPC collectors -- incident angle modifier constants have been established, along with optical losses and design parameters for low optical loss concentrating collectors. Additional required improvements will be obtained by utilizing improved selective absorber coatings (absorptivity .95, emissivity .05) and by the use of a high-reflective compound parabolic concentrator reflector (reflectivity = 95%). Research is also underway to develop high performance CPC collectors with operating temperatures in the 375°F range.

2. Absorption Chillers

Previous research activities have resulted in the development of residential (3-ton) and commercial (15-, 25-, 75, and 120-ton) chillers compatible with medium temperature solar collectors (170° - 210°F driving temperatures). These machines have demonstrated coefficients of performance (COP)=.7 in air cooled, water cooled, and evaporatively cooled configurations. While these accomplishments represent significant improvements in the state-of-the-art, it is now recognized that the performance of absorption chillers will have to be improved substantially beyond these COPs to achieve significart market penetration.

The emphasis of absorption chiller research activities in FY 1984 will be on advanced concepts capable of more than doubling COP at 300°F. If this can be achieved, it will have the effect of significantly reducing the required collector array area, and consequently reduce overall active solar cooling system costs. If, for example, collectors were available in the 280 - 350°F range with performance and cost comparable to today's collectors (in the 180 - 230° range) then a COP improvement of .7 to 1.5 would reduce the collector area requirement by a factor of 2. Specific research activities will involve continued research on a new generation of advanced double and single effect regenerative chillers. The double-effect regenerative chiller prototype is in its initial test phase.

3. Rankine Chillers

In the area of Rankine cooling technology, DOE support has resulted in the development of systems capable of achieving COP's ranging from .5 at 200°F to .9 at 300°F. System configurations incorporating electricity generation,/thermal storage, and vapor compression heat pump operation, have been successfully demonstrated. Further improvements in this technology are possible and show promise. However, they require the operation of Rankine engines at cycle temperatures over 400°F. At these temperatures, and

particularly for those Solar Rankine systems with power generating capabilities, this development borders on the Rankine cycle development supported by the Solar Thermal Technology Program. Consequently, with the limited budget available, the continued support for Solar Rankine within the Active Solar Program is seen as relatively low priority. Therefore, work in FY 1984 will be limited to the completion of a multi-year research project involving a solar/fossil fired superheated steam Rankine system.

4. Desiccant Cooling

Previous activities have already resulted in the development of a prototype solar driven solid desiccant dehumidifier capable of achieving thermal coefficients of performance greater than 1.0 Btu cooling output/Btu thermal input. Liquid desiccant systems utilizing low-cost roof top collector regenerators have also been demonstrated. These systems offer the potential of low cost. Analysis of advanced concepts such as a hybrid desiccant/vapor compression system show that in the future even higher COP's may be possible.

The FY 1984 desiccant research activity will focus on: Investigating methods for enhanced heat and mass transfer in parallel passage solid desiccant dehumidifier designs; Exploring methods to optimize dehumidifier performance through identification of improved properties of desiccant materials; evaluation of several hybrid concepts; and further evaluation of liquid desiccant open-cycle adsorption systems.

5. Balance of Systems

Previous research in solar storage has led to the development of sensible and latent storage units that are presently on the market. These include low cost site-fabricated membrane-lined water storage units for hot water and space heating applications, and a number of different phase change material/packaging combinations for use in space heating or cooling applications (both for

cool storage and higher temperature storage). The performance of these units has generally been established through lab and field tests and by analysis using specially developed computer models. Methods to increase storage efficiencies and overall effectiveness in various system configurations have been explored. In addition, some preliminary studies have been conducted on the effectiveness of large scale annual thermal storage system configurations for multiple-family and community heating have been initiated.

Due to budgetary constraints, the commercial availability of thermal storge units, and the relative uncertainty as to the probable benefits of improved storage devices in terms of system performance and cost, only a very small storage research effort will be conducted this year.

B. Systems Research

This program element is designed to provide industry with the system-level data and analysis tools necessary to support decisions regarding technology development. The focus is on collection, processing, analysis, and dissemination of thermal performance, reliability, and durability data from National Solar Data Network (NSDN) sites, and from experimental prototype heating and cooling systems developed and tested under the program.

1. Systems Simulation and Analysis

Work in this area encompasses both the testing and analysis of complete solar heating and cooling systems, and advanced components in a systems context. The analysis portion of the activity involves the development and application of simulation models to help define system performance and its sensitivity to changes in components or operating conditions. In previous years analytical tools such as TRNSYS, FCHART, and DOE2 have been developed for the design and performance prediction of various active solar heating and cooling sys-

tems. These tools are now used by large segments of both the solar research and design community.

In FY 1984, analyses will be conducted and performance models developed for such promising concepts as double effect absorption cooling hybrid vapor compression/desiccant and absorption/desiccant cooling. Hybrid systems using active collection and passive storage and distribution will be modeled as well. Comparative evaluations of these and any new material, component, and system concepts, including performance and cost assessments will also be undertaken.

2. Experimental Systems Research

The systems testing portion of the activity will emphasize work in the area of system integration. This will include conducting control optimization experiments on heating and cooling systems and identifying the R&D issues involved in a high performance system. In addition, testing of selected components and systems previously developed under the Program such as solar/gas double effect absorption chiller and a high temperature phase change material storage unit, will be undertaken to accurately determine their performance. Innovative packaged space heating systems are candidates for such testing as well.

The system effectiveness research portion of this activity is designed to collect and analyze data on system reliability and durability in order to identify research that will result in an increase in the useful life of systems and components. This is a critical need since relatively few systems have demonstrated actual 20-year-service lives (a number have shown lives of less than 10 years), and because of the importance of system durability in consumer purchase decisions. To date, program activities have resulted in the collection, analysis, organization, and dissemination of available reliability and maintainability information. Reliability and materials design guidelines for active solar domes-

tic hot water systems and active space heating systems have also been published for use by industry.

In FY 1984, system effectiveness research activities will have two major components: field data collection and evaluation, and component reliability research. The field data element will involve gathering reliability data on state-of-the-art systems under the National Solar Data Network, and the Solar in Federal Buildings Program. The objective is to establish the lifetime of active solar heating and cooling systems, and to identify factors that limit system life. The component reliability research focuses on specific aspects of failure or degradation mechanisms as they relate to various components. In FY 1984 this will include:

- Conducting exposure tests on collectors and collector materials. This builds upon the previous real time exposure testing work (up to 60 months in some instances), and provides additional, valuable data on long-term collector material response to a variety of environmental conditions

- Investigation of corrosion mechanism, particularly with various metal/fluid combinations in collector and load loops

- Research on control problems - a major area of concern even in the better systems currently available.

In addition, analyses of problems associated with other subsystem components such as storage units, pumps, fans, etc. will be undertaken. The results will be used to identify research needs and to explore possible solutions.

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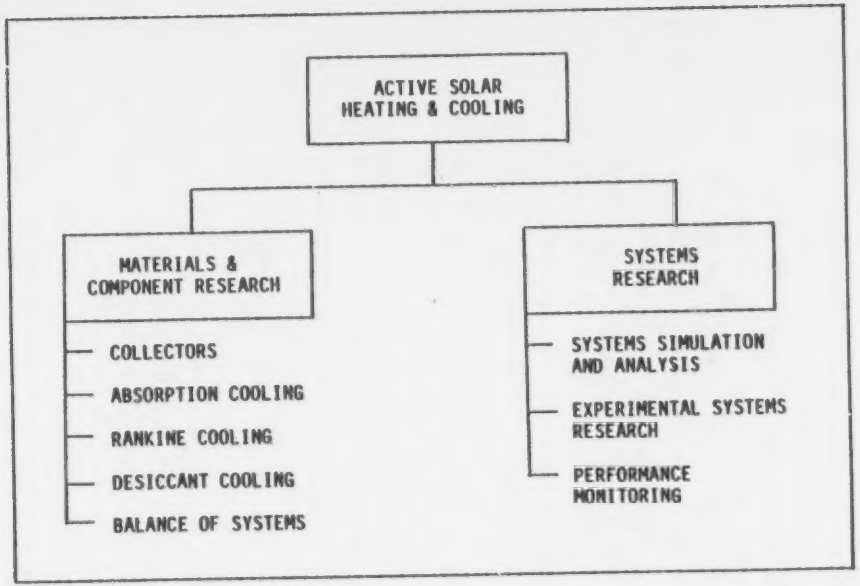
EXHIBIT 1
ACTIVE SOLAR HEATING
AND COOLING PROGRAM STRUCTURE



3. Performance Monitoring

The National Solar Data Network (NSDN) is the key data gathering element of the Active Solar Heating and Cooling Program. It provides baseline information on commercially available, field-installed systems that can be used to gauge the status of the current technology as well as future systems. It provides data on component and system deficiencies that can be used by both government and industry to help identify areas where research and product improvement are needed.

In prior years, the NSDN data has been used to validate performance prediction models such as FCHART and DOE2, to refine standardized load profiles used in developing solar hot water system tests, to upgrade the performance of demonstration project sites, and to provide selected component and systems level data to specific manufacturers and builders.

IV. PROGRAM IMPLEMENTATION AND MANAGEMENT

The Active Solar Heating and Cooling Program is implemented through a management structure that is aligned with the major program activity areas as shown in Exhibit 1. This section of the Active Solar FY 1984 AOP discusses the following: (1) management responsibilities, (2) program planning and evaluation process, (3) program funding, (4) procurement execution plan, and (5) key milestones, program milestones and project descriptions.

IV.1 Management Responsibilities

A. HQ, Lead and Technical Centers

Program responsibilities are divided among Headquarters, the San Francisco Operations Office and supporting laboratories. Headquarters has overall responsibility for the conduct of the program including policy formulation, planning and assessment. The San Francisco Operations Office manages contracts with industry and universities, and acts as the program manager for absorption and Rankine solar cooling. The Solar Energy Research Institute, Argonne National Laboratory, Brookhaven National Laboratory, Los Alamos National Laboratory, Lawrence Berkeley Laboratory and the National Bureau of Standards perform designated technical tasks. Exhibit 2 displays the field management structure and responsibilities, including the identification of lead organizations and participants for specific activity areas. Technical coordination of the research conducted in the activity areas is the responsibility of the lead organization.

B. Reporting Requirements

Management control is maintained through a schedule of periodic reporting and reviews in order to ensure that the program is proceeding as described in approved Field Task Proposal/Agreements (FTP/A). These include:

- Monthly technical and financial reports prepared by the various field organizations indicating progress relative to the FTP/A's

- Deliverables as identified and scheduled in the FTP/A and shown in Appendix A.

IV.2 Program Planning and Evaluation

The program described in this AOP is the result of planning efforts involving DOE staff, national laboratories, industry, and universities. Congressional guidance, Administration policy, and technical inputs based on a review of research needs and opportunities were used to help guide this effort. Criteria such as the ability of an activity to improve system cost effectiveness, to advance solar-related technology, and to show a favorable cost/benefit relationship were used to rank proposed work. Specific tasks and deliverables were constructed around these activities through the Field Task Proposal/Agreement development process.

Overall, progress of the program is measured against objectives established by Public Law. However, these are broadly stated, long-term objectives which do not easily lend themselves to a regular program of assessment. Therefore, a formal set of criteria and a procedure for evaluation against these criteria have been established. These closely correspond with the criteria used in the planning process that determined the funded activities. The evaluations may be viewed in three parts:

(1) Establishment of program milestones and periodic internal review of progress against these milestones

(2) Establishment of cost and performance goals and periodic internal review of progress against these goals.

(3) Periodic external review of the program by representatives from industry to provide guidance on how the government can best complement private R&D efforts.

The evaluation required in item (1) involves reviews at different levels within the DOE organization. All projects are reviewed on a monthly basis by the Division Director, Branch Chiefs, and Program Managers. Major projects and key milestones are also reviewed by the Office Director on a bi-monthly basis, and by the Deputy Assistant Secretary and the Assistant Secretary on a quarterly basis. The primary purpose of this evaluation is to identify management, technical or policy problems as they arise in the conduct of work. Resolution of these problems is the responsibility of DOE HQ management.

The evaluation required in item (2) is a quantitative assessment of project accomplishments relative to specific materials, components, and system level goals. All projects associated with a specific research path (e.g., absorption cooling, desiccant cooling, etc.) are subject to this evaluation. The cost and performance goals are subjected to periodic review, and refinements are made as necessary. Projects that appear unlikely to contribute to cost or performance improvements planned can be redirected or phased out.

The evaluation required in item (3) is designed to ensure that the program remains on track with respect to meeting industry needs. Reviews conducted by industry groups such as SEIA, ASHRAE, GRI, etc. and university researchers help serve as an efficient mechanism for obtaining information on industry viewpoints, on new private sector developments, and other factors that should properly be a part of future year programming decisions.

IV.3 Program Funding

A comparison of the program's budget for FY 1983 and FY 1984 is shown in Exhibit 3.

The allocation of funds to DOE labs, the National Bureau of Standards, and the San Francisco Operations Office for FY 1984 research, development and program management activities are shown in Exhibit 4.

IV.4. Procurement Execution Plan

Exhibit 5 presents the planned schedule for disbursements of total FY 1984 program funds to field organizations.

IV.5 Key Milestones, Program Milestones and Project Descriptions*

Exhibit 6 contains the key milestones for projects under each of the activity areas described in Section III.3. Milestone descriptions are displayed on facing pages and are numerically keyed to the milestones themselves. Key milestones are those events that are tracked at the office level or higher. In addition, alphanumeric indicators are provided for each of the projects identified. These are keyed to brief project descriptions which are contained in Exhibit 9. Exhibit 8 contains program milestones for projects funded in FY 1983 which will be completed in FY 1984. Exhibit 7 provides a "cross-walk" to identify the relationship of the key milestones in Exhibit 6 to the program milestones in Exhibit 8. Exhibit 10 is included to provide a reference with program milestones from FY 1982 funded projects that continue into FY 1983.

*This information is currently under development.

ACTIVE SOLAR HEATING & COOLING PROGRAM
PROJECT DESCRIPTIONS

Organization: National Bureau of Standards

Title: Measurement Techniques for Evaluating Reflector Materials

Description: Develop laboratory and field data on performance and durability of reflector materials and develop measurement techniques to evaluate reflector materials. Test methods which can be used to evaluate the performance and durability of proposed reflector materials under conditions of use are currently not available.

Organization: National Bureau of Standards

Title: Performance Testing of Solar Collectors

Description: In this task, NBS proposes to support U.S. activities in the International Energy Agency (IEA) project entitled "Performance Testing of Solar Collectors" (Annex III). Specific activities include participation in three IEA subtasks: (1) collector characterization, (2) service life prediction, and (3) solar domestic hot water. In addition, NBS will participate in regularly scheduled IEA meetings and prepare and present program results to appropriate U.S. groups.

Organization: National Bureau of Standards

Title: Thermal Test Methods for Solar Collectors

Description: Extend the state-of-the-art in testing and evaluating the thermal performance of solar collectors using solar simulators. The test

results from various collector testing programs demonstrate that although a collector can be tested accurately and reproducibly in a solar simulator, the results obtained at different solar simulator facilities differ among themselves and the results obtained outdoors. It is critical at this time to establish the conditions required to maintain comparability in solar simulator testing, and to determine what measurements must be made to understand the differences that do occur, before solar simulator testing becomes too well entrenched.

Organization: National Bureau of Standards

Title: Solar Hot Water Test Program

Description: Extend the current state-of-the-art in solar energy system testing and evaluation to encompass innovative solar water heaters such as thermosyphon, refrigerant-charged and breadbox systems, and to provide system performance data required to advance state-of-the-art in performance modeling. Previous research has resulted in the first evaluation procedure capable of predicting adequately the long-term performance of a solar domestic hot water system based on short-term tests, defined in ASHRAE 95-1981. The procedures which have been demonstrated to be valid for forced-circulation systems need to be extended to systems in which circulation is driven by solar input (thermosyphon and refrigerant charged) and integrated systems (bread-box) where there is only internal circulation.

Organization: Brookhaven National Laboratory

Title: High Performance Polymer Film Solar Collector

Description: For FY 83, the principal objective will be the resolution of the delamination problem experienced in FY 82. To achieve this objective, three parallel paths will be investigated: (1) further evaluation of adhesive bonded absorber laminates, (2) evaluation of laminates fabricated by both melt bonding and dispersion coating methods and (3) evaluation of bare metal foil absorbers. In FY 84, research will be concentrated in two areas: (1) bonding of polymer laminates to metallic absorber sobstrates and (2) further development of thin film collectors utilizing a bare stainless steel foil absorber capable of operational temperatures exceeding 275°F.

Organization: San Francisco Operation Office

Title: PRDA for Thin Film Collectors

Description: Initial research on low cost collectors has identified the thin film flat plate collector concept as particularly promising in terms of meeting collector performance/cost requirements. However, several issues must be addressed before such a collector can be successfully developed. These include identification of appropriate materials for glazings, laminates for absorbers, adhesives, etc. and appropriate fabrication techniques. In this PRDA DOE is inviting industry participation in the appropriate R&D to make the thin film collector practical. The emphasis will be on materials research that can lead to the development of low cost thin film collectors capable of performing on par with current high performance flat plate collectors, and exhibiting good durability.

Organization: Solar Energy Research Institute

Title: Photodegradation Resistant Polymers

Description: An in-house effort will be initiated on the stabilization of selected materials based on the data collected on available knowledge in the field. This effort will first use the more conventional approach of using commercial UV screens, stabilizers, etc., where they have not been properly tested with the selected materials. Later, the effort will be shifted to the concept incorporating stabilizers covalently into the polymer proper. These stabilization efforts will be coordinated with ongoing fundamental studies of photodegradation using FT-IR.

Organization: National Bureau of Standards

Title: Environmental Degradation of Polymeric Cover Plate Materials

Description: Characterize the moisture degradation mechanisms occurring in polymeric cover materials and develop evaluation procedures for such materials when used in humid environments. Determine the relationships between micro-structural and engineering properties of cover materials and investigate the use of micro-level changes as a tool for the early detection of materials degradation. Develop mathematical models which can be used in conjunction with short-term accelerated aging test data to predict the service life of polymeric materials. This information is required to assess the suitability of polymeric materials for use in low cost, higher performance, solar collectors.

Organization: Argonne National Laboratory

Title: Research on Advanced Collectors

Description: Research on advanced collectors building upon component work currently in progress. ANL will undertake the construction and testing of an advanced compound parabolic collector design incorporating the latest in state-of-the-art improvements. This will include high performance selective absorbers and silver film for reflective surfaces. The objective is to improve performance by 50% at 280°F.

Organization: San Francisco Operations Office/University of Chicago

Title: High Performance CPC Collectors

Description: An advanced version of the CPC collector (the ISEC) has been designed to operate continuously at temperatures exceeding 375°F. For FY 84, the focus of this program will be on array development and test and integration with high termperature cooling systems.

Organization: Lawrence Berkeley Laboratory

Title: Advanced Regenerative Absorption Chiller Research

Description: Lab testing of the double-effect regenerative (2R) chiller will be carried out during FY 1983, including design and fabrication changes as required to: (1) achieve initial chiller operation, and (2) produce stable and reproducible operation. Chiller performance will be measured over a broad range of operating conditions. If necessary to achieve chiller operation, an absorber bench test loop will be set up to investigate the detailed heat and

mass transfer occurring in the absorption processes at high (about 220°F) and low (about 100°F) temperatures. Successful demonstration of the 2 concepts would indicate great promise for developing an absorption machine capable of achieving COP's of 1.3 and greater. In addition design and analysis work on the single-effect regenerative (1R) cycle will continue at a low level of effort during FY 1983.

Organization: San Francisco Operations Office/TBD

Title: Absorption Chiller Component & Cycle Improvement

Description: A solicitation for the development of better mechanical and thermal designs and configurations for the subcomponents of absorption chillers. This work will build upon and extend the design improvements made over the past few years on heat and mass transfer in the absorber and the evaporator subcomponents. This solicitation will incorporate the results of both the Phase I absorption cycle studies (funded by DOE-Conservation) and the previously funded second law analysis, as well as cycle operating changes suggested by operating experiences at CSU and the NSDN program.

Organization: San Francisco Operations Office/University of Pennsylvania

Title: Solar/Fossil Superheated Steam Rankine Cycle Development

Description: The University of Pennsylvania-designed solar-boosted fossil (steam) turbine tests will continue in FY 84. It is anticipated that significant areas for improvement through innovative redesign will become apparent after this initial unit is tested. This is expected for any research project of this type.

Organization: San Francisco Operations Office

Title: Liquid Desiccant System Research

Description: Continue the development of an integrated heating/cooling liquid desiccant system, with the goal of increasing the energy savings of the system by 60-80% over cooling alone. Evaluate the use of combination liquid desiccant solutions, e.g., calcium chloride and lithium chloride, in order to lower cost of desiccant inventory by 40% while maintaining system performance.

Organization: Solar Energy Research Institute

Title: Development of Advanced Dehumidifier Concepts

Description: Testing of the SERI parallel-passage dehumidifier prototype has been successful in demonstrating its potential for high performance in desiccant cooling systems. The next step in developing this concept is construction and testing of a half-scale dehumidifier prototype. The test rig would be configured as a desiccant cooling system, using a rotary dehumidifier and heat exchanger and two air streams for testing the cyclic performance of the desiccant wheel. The apparatus will be capable of measuring the effect of transients on system performance through the use of advanced instrumentation. Also, the system will be designed to test hybrid system configurations using a vapor compression chiller in combination with the desiccant dehumidifier. This project will combine laboratory testing and evaluations with the simulation capabilities of the SERI DESSIM programs. Design of the laboratory test rig will include specification of instrumentation and equipment based on experience of other researcher.

Organization: Solar Energy Research Institute

Title: Investigation of Solid Desiccant Properties

Description: Analysis of experimental data, taken in the SERI Desiccant Cooling Laboratory using packed-bed and parallel-passage dehumidifiers, has indicated that absorption and desorption properties of silica gel are not the same. This points to a hysteresis effect in the cyclic operation of a desiccant cooling system. Investigation of this effect, using TRNSYS system simulations at the University of Wisconsin, indicates a possible 10-15% performance reduction if such an effect is present. Close examination of desiccant sorption behavior in low moisture-content regimes will be necessary to determine if such effects exist and how they affect dehumidifier performance. This project will use chromatograph equipment developed at SERI under a previous task to measure the kinetics of absorption and desorption in silica gel. The DESSIM simulation programs will be used to evaluate effects on dehumidifier and system performance.

Organization: Solar Energy Research Institute

Title: Analytical Evaluations of Desiccant and Hybrid Cooling Systems

Description: Several desiccant cooling systems have emerged as having promise for meeting reasonable cost/performance goals in the long-term. These systems include solid desiccant cooling systems with high-performance components, hybrid desiccant/vapor compression systems, and liquid desiccant systems with low-cost, trickle collector regeneration systems. Data from tests at SERI (solid desiccants) and the University of South Carolina (liquid desiccants) will be used to evaluate candidate systems and recommend systems that merit continued research. SERI's DESSIM simulation programs and the TRNSYS simulation programs from the University of Wisconsin will

be used to evaluate seasonal system performance based on experimental results.

Organization: National Bureau of Standards

Title: Phase Change Storage Materials

Description: Demonstrate the applicability of a preliminary mathematical model describing the loss in energy storage capacity in PCM systems. Thermal storage capacities of PCM systems tend to decrease upon thermal cycling. The applicability of the model will be tested by subjecting selected PCMs to different cycling temperatures, and heating and cooling rates. This model will be a valuable tool in predicting the service life of candidate PCMs.

Organization: San Francisco Operations Office

Title: Systems Analyses of Collector Materials Improvements and Advanced Innovative Space Conditioning Concepts

Description: Conduct systems analyses studies of the impacts of material property improvements on system performance. Simulation models such as FCHART or TRNSYS will be used in modeling component level changes in performance/operational characteristics. Develop models of advanced and innovative concepts such as hybrid space cooling using TRNSYS.

Organization: San Francisco Operations Office

Title: Analysis of System Performance with Newly Developed Technologies

Description: The work begun during the past year on computer simulation of the performance of solar cooling and heating systems will continue.

Performance of solar cooling heating systems will be analyzed using performance characteristics of newly developed components, including collectors, chillers, and storage devices, as input.

Organization: San Francisco Operations Office

Title: System Integration-Test and Analysis

Description: A primary objective of this task is to test and analyze the performance of systems using newly developed components. This will include conducting control optimization experiments on a number of heating and cooling systems, and identifying the R&D issues in successfully integrating high performance components into a high performance system.

Organization: Los Alamos National Laboratory

Title: Systems Effectiveness Research

Description: (1) Component Reliability Research - This research program will address the mechanisms of failure that limit the lifetime of solar heating and cooling systems. Research will focus on heat transfer fluids and collector materials.

(2) Evaluation and Assessment - This area of research will focus on establishing the lifetime of solar heating and cooling systems and on identifying the factors that limit system life. One major task will involve the evaluation of field data (correlation of performance loss with observations on system condition and operational history).

(3) Research Requirements - Evaluate the reliability and maintainability of advanced systems identified in the APRR task. Identify and document the research needs for the SHAC systems which arise when the technology leaves the laboratory and provides specific research priorities needed to properly address these issues.

Organization: The National Bureau of Standards

Title: Systems Effectiveness Research

Description: (1) Evaluation and Assessment - This area of research will focus on establishing the lifetime of solar heating and cooling systems and on identifying the factors that limit system life.

. Review of Historical Data - Evaluate the data base of information collected in the R&M program on system performance, reliability, and failures. This evaluation will provide a basis for identifying information needs for the field assessment activities.

(2) Research Requirements - Evaluate the reliability of advanced systems identified in the APRR task. Identify and document the research needs for the SHAC systems which arise when the technology leaves the laboratory, and provide specific research priorities needed to properly address these issues.

Organization: Solar Energy Research Institute

Title: Systems Effectiveness Research

Description: (1) Field Data Acquisition - Gather data on selected SHAC systems that will establish the useful life of state-of-the-art systems. This data will include system performance, observations on

systems condition, and interviews with owners on operational history. State-of-the-art systems will be selected on the basis of high-quality components, good design, and proper installation. Data will be gathered using the resources of the National Solar Data Network, the Federal Solar Buildings Program, and the SERI Field Acquisition Coordinating Team (FACT) activities.

(2) Component Reliability Research - This research will address the mechanisms of failure that limit the lifetime of solar heating and cooling systems. Research will focus on systems analysis, controls, and subsystem components.

(3) Evaluation and Assessments - This area will focus on establishing the lifetime of solar heating and cooling systems and on identifying the factors that limit system life.

The two primary tasks include a review of historical data and an evaluation of field data.

(4) Research Requirements - Evaluate the reliability and maintainability of advanced systems identified in the APRR. Identify and document the research needs for the SHAC systems which arise when the technology leaves the laboratory, and provide specific research priorities needed to properly address these issues.

(5) Coordination - Coordinate with related work in other national laboratories and industry, including existing mechanisms for gathering field and laboratory data.

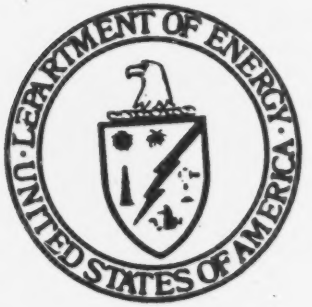
Organization: DOE Headquarters

Title: National Solar Data Network

Description: In FY 1984, the contractor will analyze the accumulated NSDN performance data and prepare reports on component performance, solar system case histories and a comparison of actual verses design performance. In addition, the contractor will research other data logging systems, and will devise a more cost effective method to collect, store and convert continuous data. The bulk of performance monitoring and analysis will be derived from the SFBP.

WORKSHOP ON BUILDING ENERGY EQUIPMENT RESEARCH

DOE ACTIVE SOLAR PROGRAM OVERVIEW



PRESENTED BY
FREDERICK H. MORSE

DECEMBER 1983

APPENDIX A2

INTRODUCTION AND PROGRAM BACKGROUND

DOE ACTIVE SOLAR PROGRAM GOALS AND STRATEGY

- o GOAL: TO DEVELOP SYSTEMS THAT COULD BE COMPETITIVE WITH CONVENTIONAL HEATING AND COOLING SYSTEMS:
  - IMPROVE COST/PERFORMANCE RATIOS BY A FACTOR OF TWO TO FOUR
  - IMPROVE RELIABILITY AND DURABILITY TO ASSURE 20-YEAR SERVICE LIFE

- o STRATEGY: TO ADVANCE THE STATE-OF-THE-ART OF ACTIVE SOLAR:
  - SUPPORT LONG-TERM/HIGH RISK RESEARCH THAT CANNOT OR WILL NOT BE UNDERTAKEN BY THE PRIVATE SECTOR
  - SUPPORT TECHNOLOGY DEVELOPMENT ACTIVITIES FOR THE NEAR-TERM

CHANGES IN ACTIVE PROGRAM EMPHASIS

1974 - 78 INITIAL FOCUS ON DEMONSTRATIONS

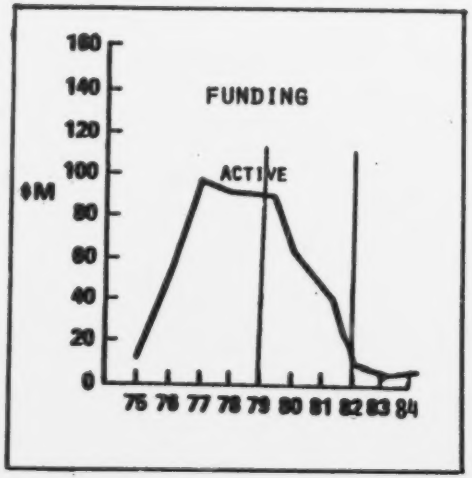
- o RESIDENTIAL & COMMERCIAL DEMOS
- o COMMERCIAL
- o COMPONENT-ORIENTED R&D

1978 - 81 MARKET ORIENTED COMMERCIALIZATION

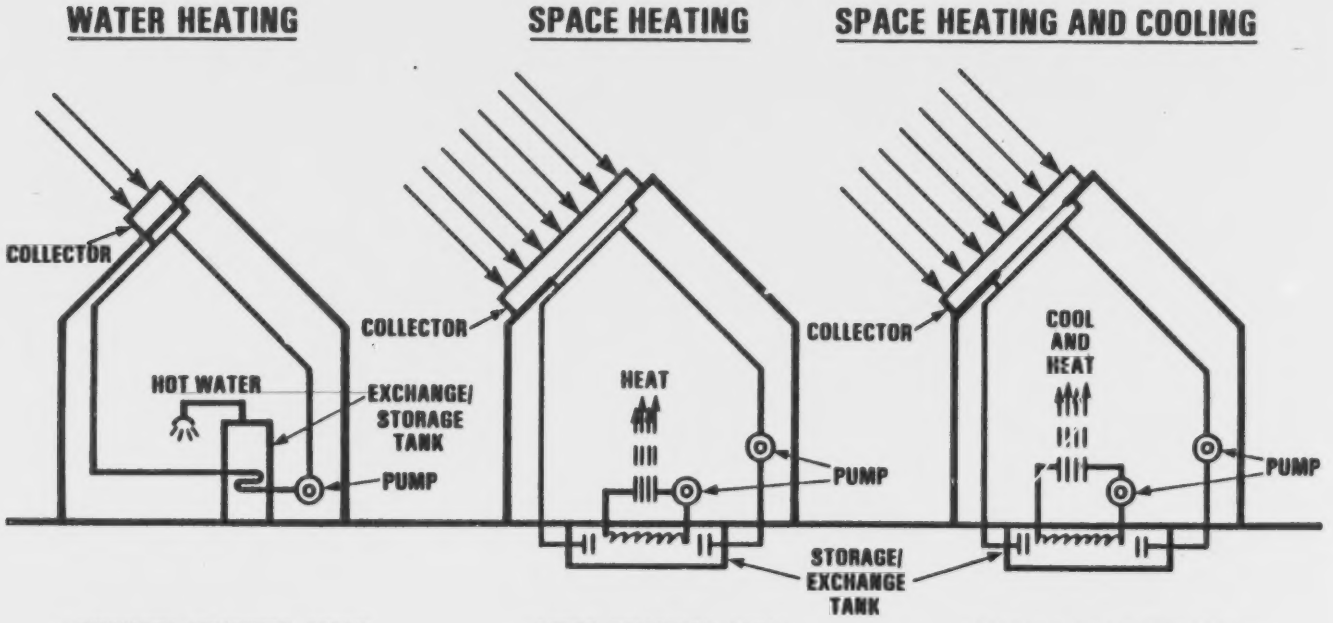
- o SOLAR IN FEDERAL BUILDINGS PROGRAM
- o REGIONAL SOLAR ENERGY CENTERS
- o INFORMATION & TRAINING, CODES & STANDARDS
- o SYSTEMS-ORIENTED R&D

1981 - NOW LONG-TERM, HIGH-RISK, HIGH-PAYOFF R&D

- o SYSTEMS ANALYSIS
- o MATERIALS & COMPONENTS R&D
- o PROTOTYPE SYSTEMS TESTING



TECHNOLOGY STATUS

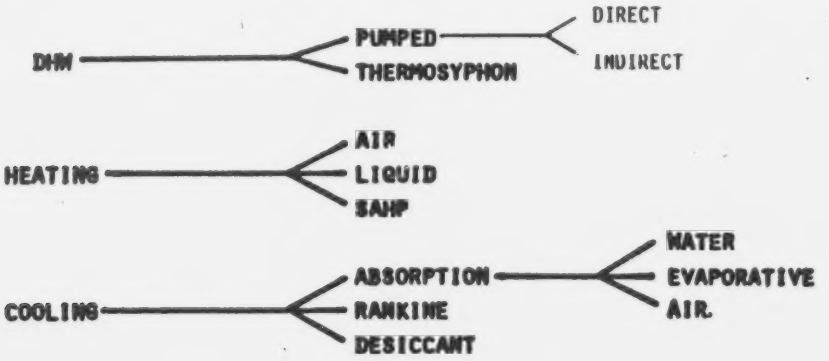


- SMALLEST COLLECTOR ARRAY
- SIMPLEST DESIGN
- LOWEST COST/EASILY RETROFIT

- LARGE COLLECTOR ARRAY
- LARGE HEAT STORAGE REQUIREMENT
- HIGH COST

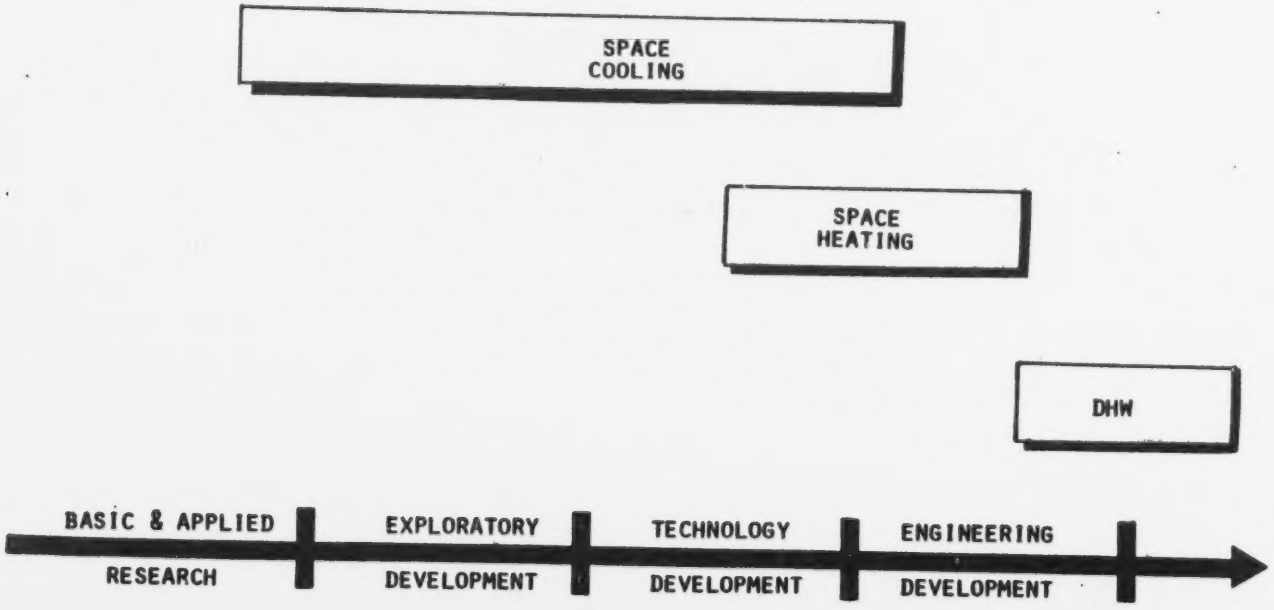
- LARGEST COLLECTOR ARRAY
- HIGHEST TEMPERATURE
- COMPLEX MECHANICAL PROCESS

ACTIVE SOLAR TECHNOLOGIES

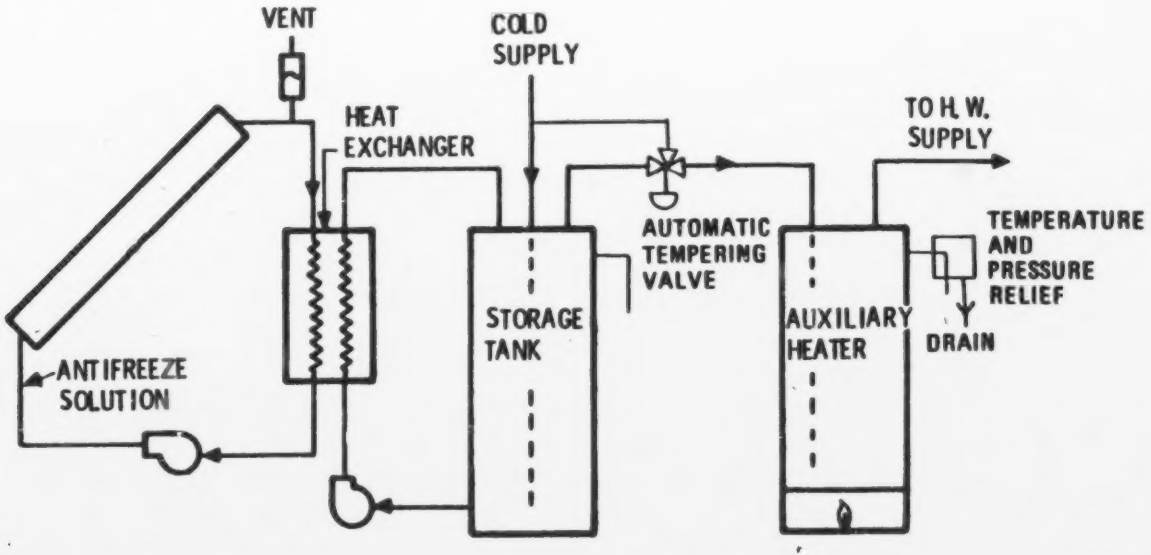


TECHNOLOGY STATUS

- ACTIVE -



SOLAR HOT WATER SYSTEM

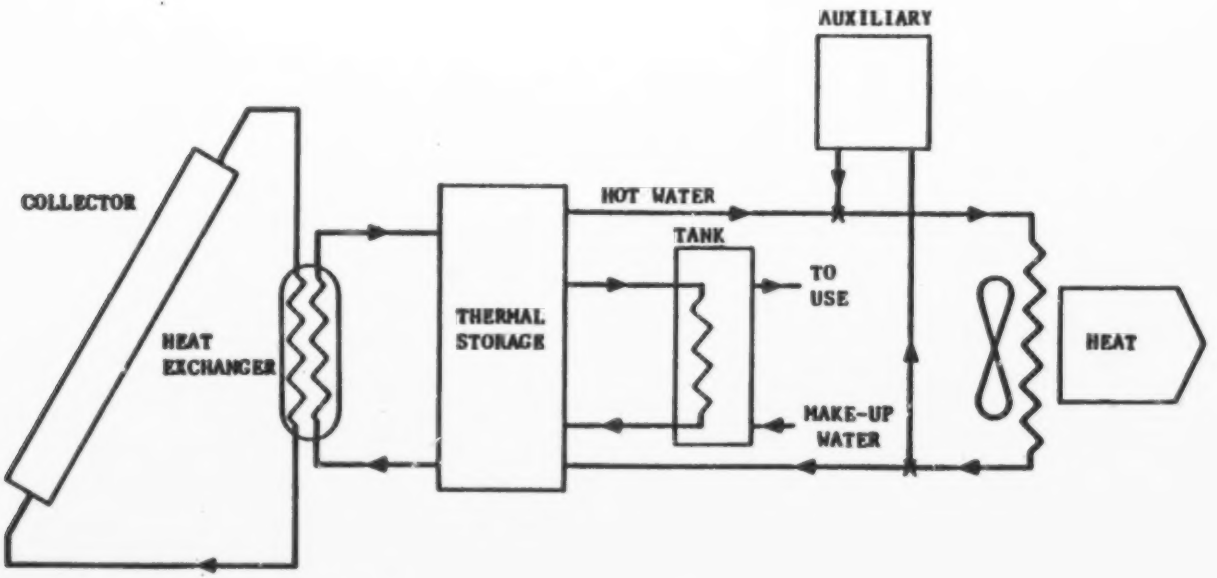


- o TECHNOLOGY STATUS
  - EVOLUTION TOWARDS PACKAGED SYSTEMS
  - EMERGENCE OF LOWER COST BATCH SYSTEMS
  - RISE IN USE OF A TWO TANK DRAIN BACK SYSTEM
  - PERFORMANCE STUDIED -- STANDARDS UNDER DEVELOPMENT

DOE PROGRAM ACCOMPLISHMENTS IN HOT WATER SYSTEMS

- PRODUCED AND PUBLISHED DESIGN HANDBOOKS AND VALIDATED DESIGN TOOLS
- SUPPORTED DEVELOPMENT OF 10,500 RESIDENTIAL, 70 COMMERCIAL, AND 700 FEDERAL HOT WATER SYSTEMS
- ESTABLISHED TECHNOLOGY BASE FOR INDUSTRY COLLECTOR AND WATER HEATER RATING AND CERTIFICATION (ASHRAE 93-77, ASHRAE 95-81)
- SUPPORTED DEVELOPMENT OF A SERIES OF TEST METHODS FOR CRITICAL COMPONENT MATERIALS INCLUDING COLLECTOR GLAZINGS, INSULATION, AND ABSORBER COATINGS WHICH WERE ADOPTED BY ASTM

SOLAR HEATING AND HOT WATER SYSTEM



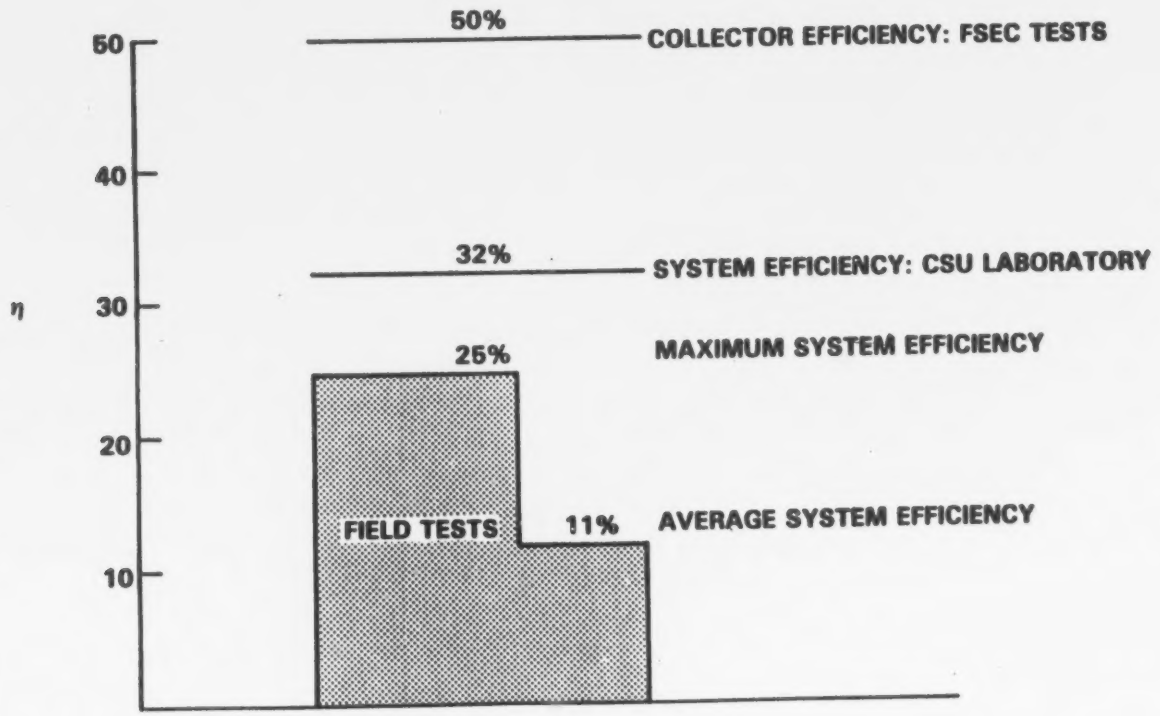
TECHNOLOGY STATUS

- GENERALLY NOT PACKAGED
- PERFORMANCE BELOW PREDICTION
- CONTROLS FAR FROM OPTIMAL
- DESIGN AND SYSTEM INTEGRATION EMERGING AS MAJOR CHALLENGE
- LITTLE INDUSTRY R&D DUE TO LACK OF FINANCING

DOE PROGRAM ACCOMPLISHMENTS IN SPACE HEATING SYSTEMS

- DEVELOPED SEVERAL SOLAR-ASSISTED HEAT PUMPS HAVING COPS OF 6-10
- SPONSORED RESEARCH ON PACKAGED SOLAR SPACE HEATING SYSTEMS
- SUPPORTED DEVELOPMENT AND TESTING OF OVER 500 SOLAR SPACE HEATING SYSTEMS INCORPORATING NEW COMPONENTS AND DESIGN CONFIGURATIONS
- CONDUCTED FIELD TESTS AND REPORTED PERFORMANCE RESULTS FROM 7% SPACE HEATING SYSTEMS FOR RESIDENTIAL AND COMMERCIAL INSTALLATIONS
- DEVELOPED IMPROVED SELECTIVE SURFACES, LOW COST PLASTIC FILMS, AND STORAGE COMPONENTS TO INCREASE RELIABILITY AND LOWER COST OF SOLAR HEATING SYSTEMS

COMPARISON OF LAB & FIELD RESULTS WITH
"IDEAL" SPACE HEATING SYSTEMS



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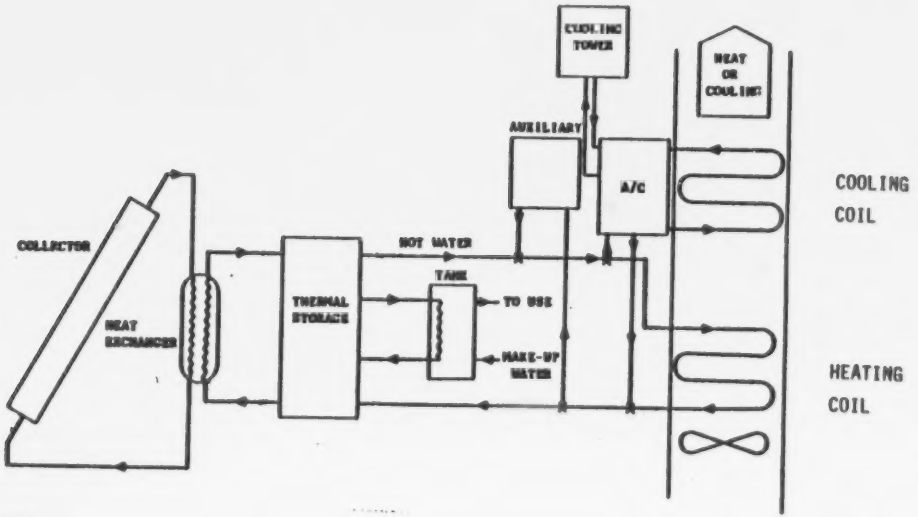
SOLAR HEATING AND COOLING SYSTEM



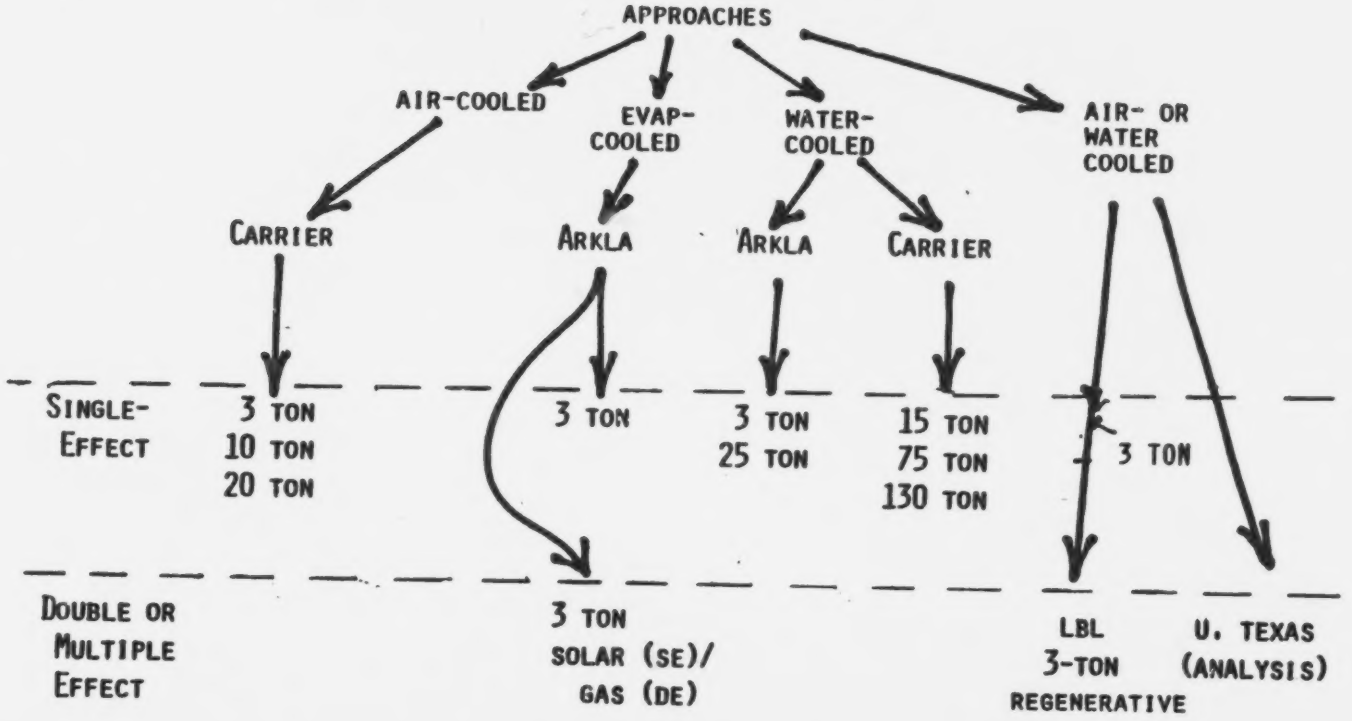
TECHNOLOGY STATUS:

- FIRST GENERATION SOLAR COOLING SYSTEMS AVAILABLE
- PROBLEMS SAME AS SPACE HEATING
- PERFORMANCE TOO LOW AND SYSTEMS MUCH TOO EXPENSIVE
- HVAC INDUSTRY UNWILLING TO FUND R&D

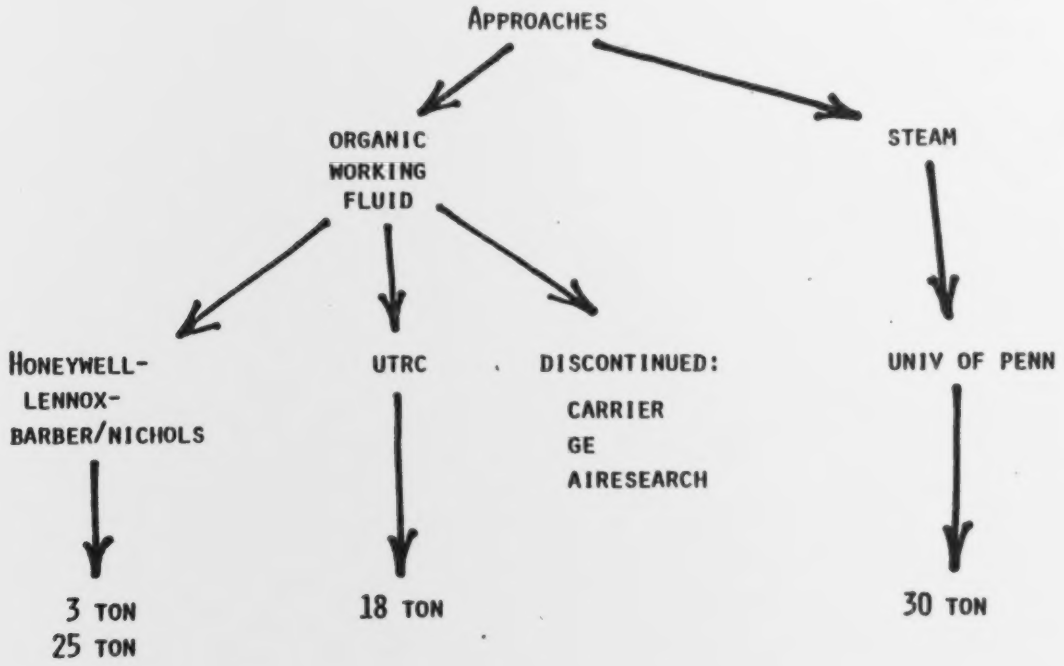
DOE PROGRAM ACCOMPLISHMENTS IN COOLING SYSTEMS

- DEVELOPED SOLAR ABSORPTION CHILLERS RANGING IN SIZE FROM 3-130 TONS ACHIEVED STEADY STATE COP'S OF 0.75
- SUCCESSFUL OPERATION OF SOLAR RANKINE SYSTEMS WITH POWER GENERATION AND HEAT PUMP CAPABILITIES
- TESTED FLUIDS AND FLUID ADDITIVES FOR LONG-TERM STABILITY IN HIGH TEMPERATURES ABSORPTION AND RANKINE CYCLE MACHINES
- DEVELOPED OPEN CYCLE SOLID DESICCANT CHILLERS FOR RESIDENTIAL APPLICATIONS
- VERIFIED USE OF OPEN-FLOW COLLECTOR/REGENERATORS FOR LIQUID DESICCANT AND OPEN CYCLE ABSORPTION SYSTEMS
- DEVELOPED PROTOTYPE INTEGRATED STATIONARY CONCENTRATING COLLECTOR (CPC) FOR HIGH TEMPERATURE COOLING OR INDUSTRIAL PROCESS APPLICATIONS (350°F OR HIGHER)
- DEVELOPED PHASE CHANGE MATERIAL STORAGE FOR HOT SIDE (240°F) OR COLD SIDE (45°F) STORAGE

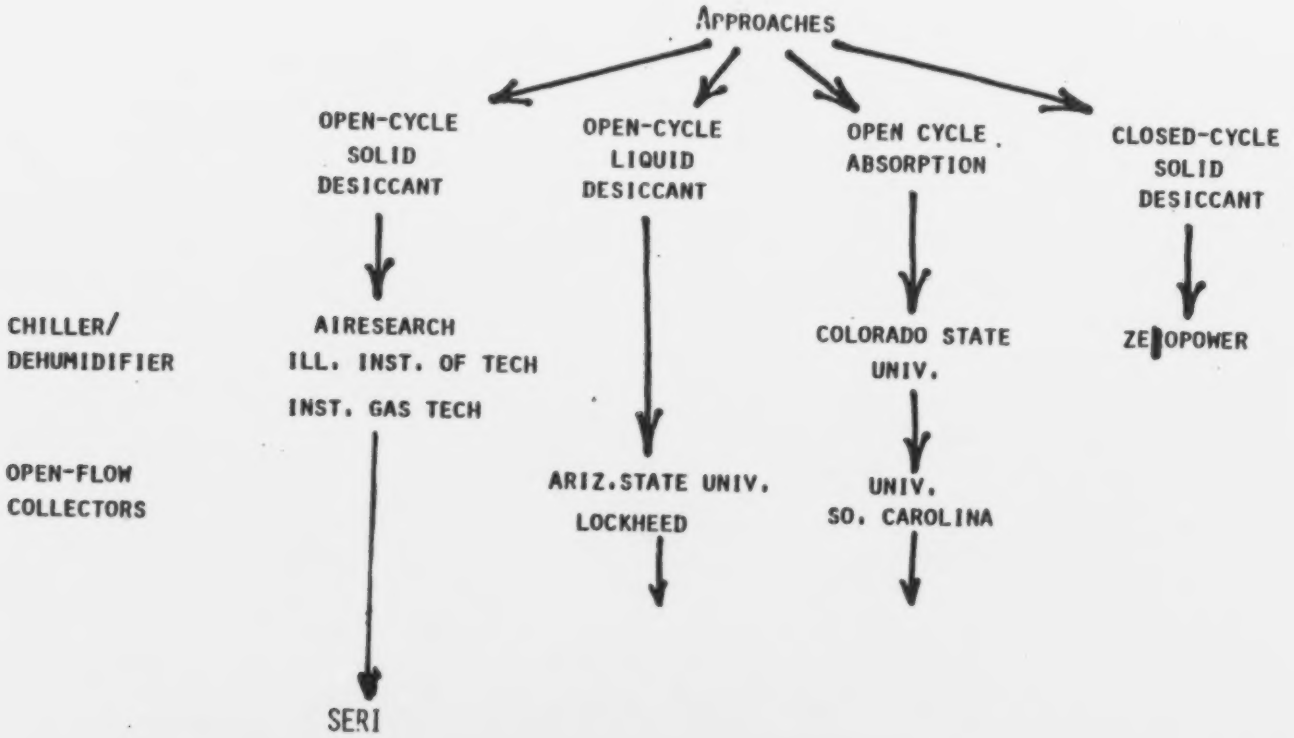
ABSORPTION CHILLER R&D



RANKINE CHILLER R & D



DESICCANT COOLING R & D

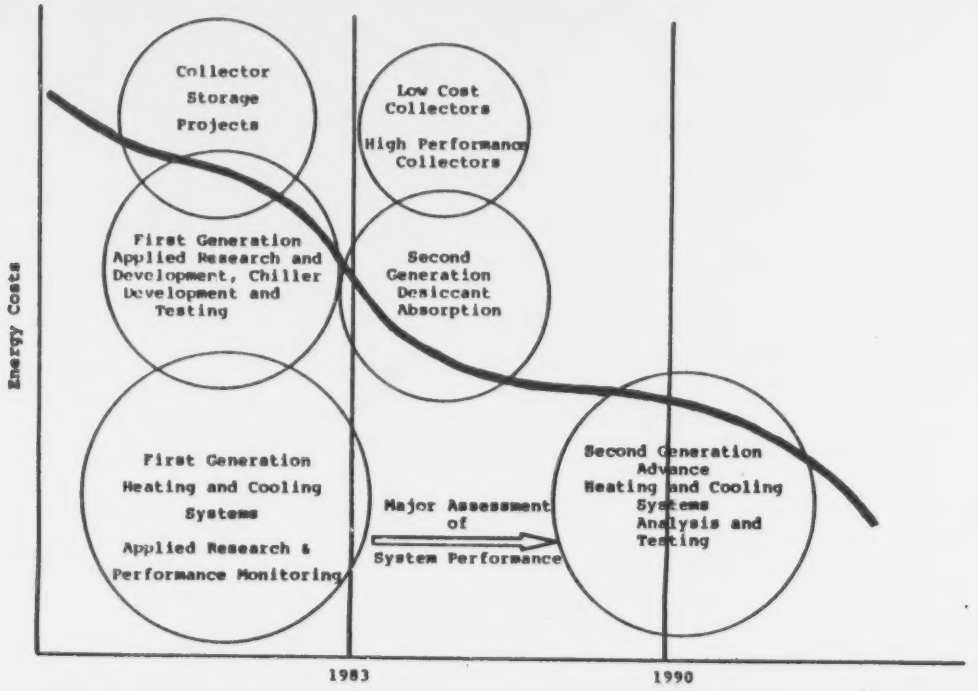


CURRENT PROGRAM

AND

RESEARCH DIRECTIONS

ACTIVE SOLAR ENERGY MULTIYEAR PROGRAM



PROGRAM RESEARCH AREAS

RESEARCH ACTIVITIES AND PRIORITIES ARE A RESULT OF ONGOING PLANNING PROCESS. ANALYTICAL FRAMEWORK IS PROVIDED BY THE ACTIVE PROGRAM RESEARCH REQUIREMENTS PROJECT (APRR). MAJOR AREAS RECEIVING PROGRAM SUPPORT INCLUDE:

- COLLECTORS
- HEATING/COOLING EQUIPMENT (CHILLERS)
- SYSTEMS SIMULATION AND ANALYSIS
- EXPERIMENTAL SYSTEMS
- PERFORMANCE MONITORING

PROGRAM BUDGET, FY 1983-84
(IN MILLION $s)

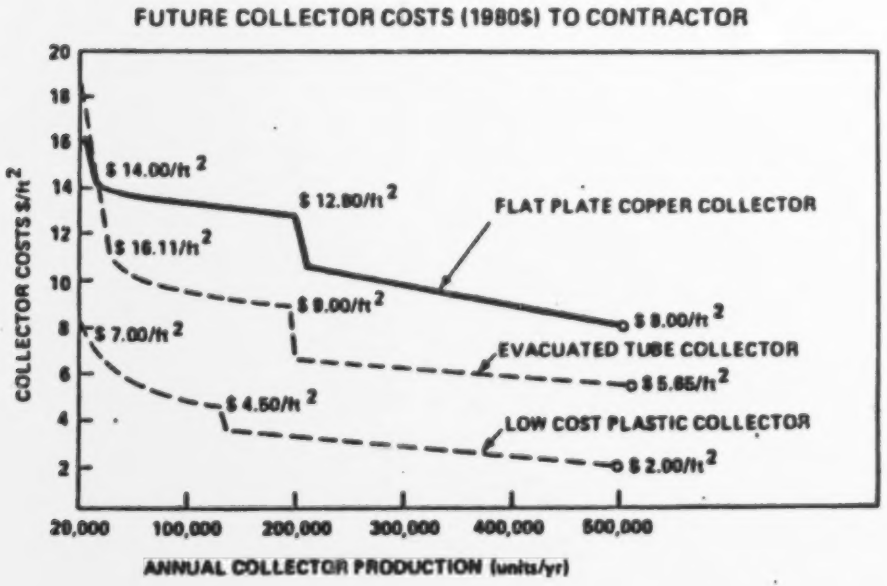
	FY 1983	FY 1984
MATERIALS & COMPONENT RESEARCH		
o COLLECTOR R&D	1.8	2.3
o HIGH PERFORMANCE-LOW COST POLYMERS/THIN FILMS		
o COMPOUND PARABOLIC COLLECTORS		
o CORROSION & DEGRADATION STUDIES, TEST METHODS		
o HEATING AND COOLING EQUIPMENT R&D		
o SOLID & LIQUID DESICCANT DEHUMIDIFIERS	.7	1.3
o SINGLE & MULTI-EFFECT ABSORPTION CHILLERS/ ADVANCED HIGH TEMP, SOLAR RANKINE CHILLERS	1.2	1.6
SYSTEMS RESEARCH		
o SYSTEM SIMULATION & ANALYSIS	1.0	1.1
o EXPERIMENTAL SYSTEMS RESEARCH	1.4	1.2
o PERFORMANCE MONITORING	.7	.3
o DESIGN INFORMATION/TECHNOLOGY TRANSFER	.2	.0
PROGRAM PLNNING & MANAGEMENT	.5	.6
	7.5	8.4

COLLECTORS

IMPROVEMENTS IN COLLECTOR PERFORMANCE/COST IS A PREREQUISITE FOR THE SUCCESSFUL DEVELOPMENT OF COMPETITIVE SOLAR HEATING AND COOLING SYSTEMS.

- o MEDIUM TEMPERATURE COLLECTORS RESEARCH:
  - PHOTOTHERMALLY STABLE POLYMER COVER MATERIALS: DEGRADATION STUDIES
  - THIN FILM, FLAT PLATE COLLECTOR PRDA.
  - DEVELOPMENT OF THIN STAINLESS FOIL COLLECTORS
- o HIGH TEMPERATURE COLLECTOR RESEARCH:
  - IN-SITU VAPOR GENERATING CPC COLLECTORS.
  - ADVANCED CPC COLLECTOR CONCEPTS FOR 300-400°F. APPLICATIONS.

COLLECTOR COST REDUCTION POTENTIAL



HEATING/COOLING EQUIPMENT

RESEARCH ACTIVITIES IN THIS AREA WILL PROVIDE LONG-TERM FUNDAMENTAL IMPROVEMENTS IN SUBSYSTEM COEFFICIENTS OF PERFORMANCE (COP).

- o ABSORPTION CHILLERS:
  - DEVELOPMENT OF DOUBLE EFFECT (2R) REGENERATIVE CHILLER AND SINGLE EFFECT (1R) REGENERATIVE SYSTEM
  - ADVANCED HIGH TEMPERATURE MULTI-EFFECT CHILLERS
- o RANKINE CHILLERS:
  - SOLAR/FOSSIL FIRED SUPERHEATED STEAM SYSTEM
  - ADVANCED HIGH TEMPERATURE RANKINE CYCLES
- o DESICCANT COOLING:
  - SPIRAL WOUND PARALLEL PASSAGE SOLID DESICCANT
  - OPEN CYCLE LIQUID DESICCANT SYSTEM WITH ROOF-TOP REGENERATOR COLLECTOR
  - ALTERNATIVE DESICCANT MATERIALS INVESTIGATIONS (E.G., MAGNESIUM OXIDES)

APPENDIX A3

Department of Energy
Washington, D.C. 20585

Dr. Eugene Frankel
Science Consultant
Committee on Science and Technology
House of Representatives
Washington, D.C. 20515

Dear Dr. Frankel:

Enclosed is the information you requested for transmittal to participants in the Building Energy Equipment Research Workshop. This material describes the program in my branch only and does not address programs in the Office of Renewable Energy. The enclosed material has been approved for dissemination by the Acting Assistant Secretary for Conservation and Renewable Energy.

We look forward to participating in the workshop.

If you require further information or clarification, please call me on 252-9130.

Sincerely,

John Ryan, Acting Chief
Energy Conversion Equipment Branch
Building Equipment Division
Building Energy Research & Development
Office of Conservation & Renewable Energy

Enclosure

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U.S. Dept of Energy
Conservation & Renewable Energy
Office of Buildings Energy R&D

III. Building Equipment Programs

A. Overview

The mission of the Building Equipment Program is to provide the long range technical support needed to supply the private sector with the technological basis for developing and testing high efficiency equipment utilized in the operation of residential and commercial buildings. This equipment supplies the heating, cooling, lighting, hot water, and other services required to operate a building efficiently and offer its occupants a comfortable environment. The Program supports applied research in the engineering phenomena surrounding the conversion of raw energy in the form of oil, gas, and electricity into the useful energy form of heat, refrigeration, and light. The research is aimed at the high risk technological problems which the private sector can not undertake alone and which must be resolved to ensure the development by the private sector of energy saving equipment for buildings. The Program supports the development, revision, and update of the DOE test procedures for consumer products. These test procedures are utilized by all manufacturers of the 13 major residential appliances to compute the energy information required for appliance energy guide labels, and to substantiate advertising claims regarding energy savings.

B. Program Areas

1. Building Equipment R&D Programs

a. Objectives

The objective of the Research and Development Program is to initiate, manage, evaluate and transfer research in technologies for improving the energy-efficiency of equipment used to supply heating, cooling, lighting, hot water, and other services required to operate a building and to offer its occupants a comfortable, healthful and safe environment. The research is primarily aimed at high-risk, generic, engineering problems which the private sector cannot or is unwilling to investigate alone, but which, if resolved, would assist private-sector development of cost-effective, energy-efficient equipment for buildings. Research programs thus investigate, develop, and test engineering approaches to the conversion of energy in the form of oil, gas, solid fuels and electricity into useful energy as heat, refrigeration, and light, and assess health, safety, and environmental effects of these technologies.

Specific long-range objectives are identified with each of the major end-use areas: space heating and cooling, water heating, lighting, refrigeration and appliances. For space heating, the objectives are a) a reduction of up to 45% in fuel usage through application of thermally-activated heat pumps and b) a reduction of up to 40% in the energy consumption of electric heat pumps. For water heating, the objective is a reduction of up to 45% through use of advanced insulation and/or thermally-activated heat pumps. For refrigeration, the objectives are reductions of up to 40% through use of advanced insulation and advanced refrigeration systems. In the lighting area, the objective is a reduction of up to 50% electrical consumption through improvements in light source efficiency and demand reduction by means of lighting controls.

b. Strategy

In keeping with the scope of the government role in developing technologies which will ultimately be commercialized solely by the private sector, the Building Equipment Research and Development Program encompasses those activities which will bring a new technology to the point of "technology readiness," from whence it can be picked up by the private sector. This includes developing the information necessary to enable the private sector to make an informed decision on committing their own resources to further development and eventual commercialization. As the point of technology readiness nears, jointly-funded industry - government efforts would be a typical operating strategy.

The type of research and development efforts undertaken by the program mainly fall into the following R&D categories: a) Research - which consists of the pursuit of fundamental, preliminary knowledge of basic phenomena, processes and materials, b) Exploratory Development - which consists of the application of basic knowledge or the solution of specific problems aimed at evaluating the practicability of technologies. c) Advanced Development - which consists of the development of hardware for proof of concept testing and the identification of systems problems requiring exploratory development.

The research consists of long-range, high-risk research on technologies which have a potential for high payoff in energy conservation and which would not be pursued by the private sector. The assessment of risk is done within the framework of the risk acceptance criteria and technical capability of the private sector. In the extremely cost competitive building equipment industry historically little advanced R&D has been performed and a planning horizon of 2 to 3 years is employed, precluding significant advanced R&D efforts. Also, energy conservation is often not a major factor in market choices among competing products.

The need to pursue advanced R&D which is not duplicative of private sector activity but rather which industry will readily accept and commercialize if it is pursued adequately requires a very strong liaison with the private sector. The program maintains strong relationships with the Electric Power Research Institute and the Gas Research Institute, among others. Close cooperation with manufacturers and trade groups is also undertaken.

c. Program Activities - See Attachments

d. Program Management Plan

The Building Equipment Program, in recognition of existing technical resources residing in the National Laboratories and the limited management resources available at DOE Headquarters, has established decentralized management plan. Under this operating approach, programmatic direction, policy making, coordination, budgeting and long-range planning are performed at DOE Headquarters. Program implementation, project management and monitoring, and technical coordination and evaluation are performed at the National Laboratories. The scope of the laboratory involvement in R&D projects management encompasses all activities from issuance of competitive solicitations, through project monitoring and, eventually, technology transfer.

The laboratory program management role described above is augmented by an in-house laboratory research program. This program complements the subcontracted efforts and both are planned and coordinated as a total program. In addition to their contribution to advancing technology, the in-house laboratory efforts improve the planning and management functions by providing an available resource for unbiased technical input.

Presently, the program is organized into four major program areas. These areas and the National Laboratory with delegated management responsibility are as follows:

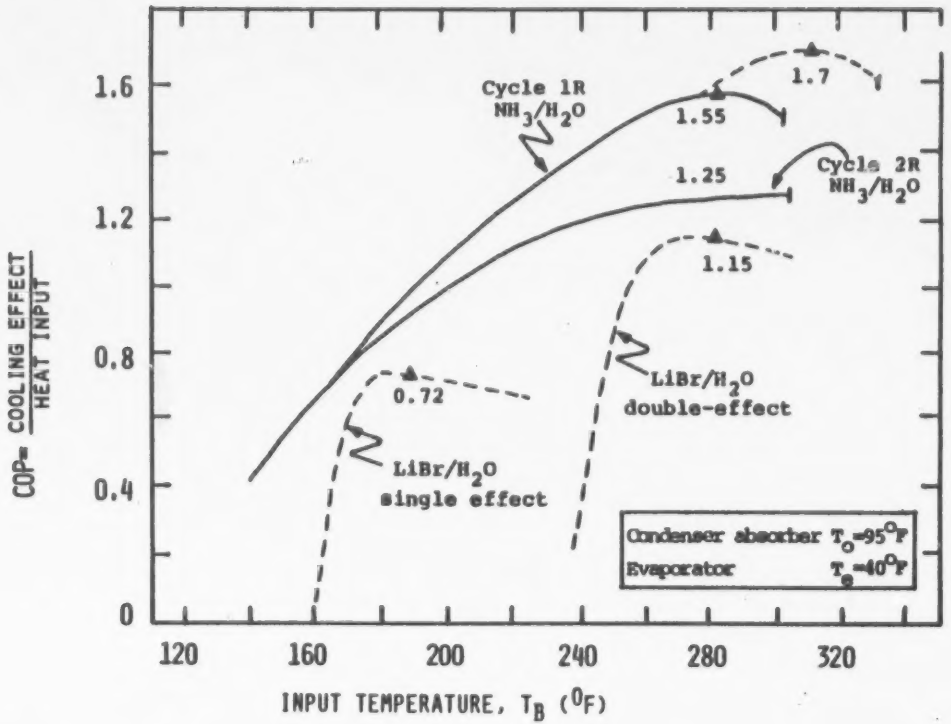
Combustion Heating Equipment
- Brookhaven National Laboratory

Thermally-Activated Heat Pumps
- Oak Ridge National Laboratory

Refrigeration and Appliance Technology
- Oak Ridge National Laboratory

Lighting
- Lawrence Berkeley National Laboratory

PERFORMANCE OF SOLAR-DRIVEN ABSORPTION CHILLER



SYSTEMS RESEARCH

- o SYSTEMS SIMULATION AND ANALYSIS
  - SPACE HEATING SYSTEMS: HYBRID ACTIVE/PASSIVE SYSTEMS
  - TRNSYS MODELING OF HYBRID SOLID DESICCANT/VAPOR COMPRESSION
  - OPEN CYCLE ABSPORTION AND LIQUID DESICCANT MODEL
  - MULTIEFFECT ABSORPTION SYSTEMS ANALYSIS
- o EXPERIMENTAL SYSTEMS RESEARCH
  - OPEN CYCLE ABSOPRTION TESTS (PACKED COLUMN REGENERATOR)
  - ABSORPTION COOLING SYSTEM WITH HIGH TEMPERATURE PHASE CHANGE MATERIAL STORAGE
  - INNOVATIVE PACKAGED HEATING SYSTEMS
  - SYSTEM INTEGRATION AND CONTROL
  - SYSTEM EFFECTIVENESS RESEARCH STUDIES
- o PERFORMANCE MONITORING
  - NATIONAL SOLAR DATA NETWORK

PROGRAM DIRECTIONS

- o LOW COST AND DURABLE ALTERNATE COLLECTOR MATERIALS
  - THIN FILM/FOIL ABSORBERS
  - TEMPERATURE - UV RESISTANT POLYMERS
- o HIGH PERFORMANCE DESICCANT SYSTEMS
  - ADVANCED DESICCANT BED DESIGNS
  - HYBRID DESICCANT - VAPOR COMPRESSION CYCLE CONCEPTS
  - DIRECT SOLAR REGENERATED LIQUID DESICCANTS
- o OPTIMIZING SYSTEM CONTROLS
  - APPLICATION OF MICRO-PROCESSORS
  - IMPROVED CONTROL STRATEGIES
- o HIGH PERFORMANCE ABSORPTION AND RANKINE TECHNOLOGY
  - REGENERATIVE ABSORPTION PROCESSES
  - THERMALLY PUMPED FLUIDS
  - INTEGRATED GAS BACKUP
  - HIGH TEMPERATURE RANKINE (350-500°F)

BUILDING AND COMMUNITY SYSTEMS
KEY ACTIVITY SUMMARY

15 NOV 1983

PROGRAM AREA OBJECTIVE	KEY ACTIVITY	FY 1983 ACTUAL ACTIVITIES	FY 1984 ESTIMATED ACTIVITIES
COMBUSTION HEATING EQUIPMENT Objective Develop generic technologies to improve the efficiency of oil & gas combustion heating systems to 90-95%; improve the safety and efficiency of residential coal and wood combustion systems to 85-90%. (Program managed by Brookhaven Nat'l Laboratory)	Condensing Heat Exchangers	Materials for Condensing HX Completed corrosion testing including stress corrosion properties of metallic materials; assessed ceramic and plastic material systems for potential applications in condensing heat exchangers.	Perform accelerated long life testing of selected new material systems under corrosive gas condensates and characterize chloride impact on corrison mechanism. Evaluate potential of condensing technology.
		Heat Transfer in Condensing Systems Completed experimental verification of the Colburn-Hougen model for a cross-flow, heat exchanger configuration.	Initiate heat transfer correlation analysis, characterization of condensing heat exchanger design concepts and optimization methodology for condensing mode heating equipment.
		Burner Technology for Condensing System Developed basic combustion technology for condensing heating systems - investigated sooting characteristics of oil burners.	Complete burner sooting characterization; initiate assessment of benefits and state-of-the-art of low-firing rate oil burners, and establish burner technology R&D needs for condensing heating systems.

BUILDING AND COMMUNITY SYSTEMS
KEY ACTIVITY SUMMARY

PROGRAM AREA OBJECTIVE	KEY ACTIVITY	FY 1983 ACTUAL ACTIVITIES	FY 1984 ESTIMATED ACTIVITIES
	Heat Distribution & Integration	Warm Air Systems Performed field experiments for verification of computer model analyzing the dynamic interactions between central heating furnace and building.	Continue field verification and computer modelling of the dynamic interactions of the central heating furnace and building.
		Hydronic Systems Completed survey on hydronic equipment technology.	Develop computer model for evaluation and optimization of hydronic heating systems.
		Conducted investigation of distributed heating and related control parameters vs. energy savings potential.	Assess control parameters for equipment use/requirements in low heat lost building envelopes.
		Radiant Heating Technology Assessed energy conservation potential of distributed radiant heating concepts including subspace utilization, and human comfort factors.	Perform laboratory and field experiments to develop data on the characteristics and performance of radiant heating systems.

APPENDIX B

GAS RESEARCH INSTITUTE
1984-1988
Five-Year Research and Development Plan
and
1984 Research and Development Program

Approved by the
GRI Board of Directors
April 6, 1983

Gas Research Institute
8600 West Bryn Mawr Avenue
Chicago, Illinois 60631

BUILDING AND COMMUNITY SYSTEMS
KEY ACTIVITY SUMMARY

PROGRAM AREA OBJECTIVE	KEY ACTIVITY	FY 1983 ACTUAL ACTIVITIES	FY 1984 ESTIMATED ACTIVITIES
	Wood and Coal	Investigated wood combustion mechanism: initiated characterization of organic products from burning wood and properties of combusted wood.	Complete characterization of organic products and begin characterization of combusted wood properties.
		Developed advanced measurement technology for solid fuel heating systems - sensors and fuel combustion detection methods.	Continue development and verification of measurement technique, for solid fuel fired systems; transfer to industry. Assess processed solid fuel, combustion and equipment technologies.
		Completed investigation of wood burning fire safety and hazard of chimney connectors and venting systems.	Investigate coal combustion safety in residential heating systems.
TOTAL COMBUSTION HEATING EQUIPMENT		2000K	1800K

BUILDING AND COMMUNITY SYSTEMS
KEY ACTIVITY SUMMARY

PROGRAM AREA OBJECTIVE	KEY ACTIVITY	FY 1983 ACTUAL ACTIVITIES	FY 1984 ESTIMATED ACTIVITIES
THERMALLY	Absorption Technology		
Thermally Activated Heat Pumps	Advanced Cycles	Continued analysis of novel concepts for advanced absorption cycle heat pumps. Initiated development of proof-of-concept of selected advanced cycle.	Continue development of proof-of-concept advanced absorption heat pumps. Initiate testing and evaluation of first-generation systems. Identify problem areas and modifications. Verify computer code.
Objective: To advance generic technologies for fuel-fired (thermal heat pumps with potential space heating "efficiencies" of 150 to 180% (fuel-based) coefficient of performance of 1.5 to 1.8)	Fluids Research	Initiated assessment and evaluation of existing absorption fluids pairs. Initiated properties data survey. Identified needed new property data.	Expand properties data of existing fluids pairs. Develop a data base for selected pairs for use with heat pumps. Initiate novel fluid pairs research.
(Program managed by Oak Ridge Nat'l Laboratory)	Heat Engine Driven Technology		
	Stirling Engine (FPSE)	Continued development and testing of initial design of a FPSE driven, diaphram actuated, hydraulic coupled compressor. Developed a control concept for matching compressor load to engine. Identified development needs to meet performance goals.	Complete initial component system testing. Evaluate engine and compressor performance. Develop plan to incorporate compressor modifications into advanced system and implement.
		Continued generic research in computer codes, thermodynamics and loss mechanisms.	Continue generic supporting research and validate FPSE Computer Code.
	IC Engine	Continued development and proof-of-concept testing of linear Otto engine driven heat pump compressor for light commercial applications. Developed control methodology for engine to compressor coupling. Defined modification needs for system improvements.	Complete proof-of-concept testing of linear Otto engine driven heat pump compressor. Implement control scheme and verify. Identify needed modification for system improvements. Investigate novel engine/compressor sealing techniques.
TOTAL, THERMALLY-ACTIVATED HEAT PUMPS		2100K	2400K

PROGRAM AREA OBJECTIVE	KEY ACTIVITY	FY 1983 ACTUAL ACTIVITIES	FY 1984 ESTIMATED ACTIVITIES
REFRIGERATION Refrigeration Systems and Appliance Objective To develop basic data and advance generic technologies applicable to heat pumps, refrigeration systems and appliances. (Program managed by Oak Ridge Nat'l Laboratory)	Heat Exchanger Technology	Continued test and evaluation of vertical and horizontal ground coupled heat exchangers. Modified heat pump design code to incorporate ground coupled heat exchangers. Began investigation of soil heat transfer phenomena.	Continue testing of ground coupled heat exchangers. Verify modifications to heat pump design code. Assess system economics. Continue soil heat transfer research and correlate with field results.
	Air-To-Air Heat Pump	Continued laboratory testing to determine dynamic losses induced thru cycling, frosting and defrosting. Analyzed and evaluated novel concepts for variable capacity heat pumps.	Implement recommended decision changes and operating techniques to reduce dynamic losses. Continue component evaluation of novel concepts for variable capacity modulated heat pumps.
	Non-Azeotropic Refrigerant	Evaluated use of non-azeotropic refrigerant mixtures in Rankine cycle vapor compression systems. Continued laboratory research and experimentation on non-azeotropic refrigerant mixtures to characterize thermodynamic and fluid properties.	Continue evaluation of non-azeotropic refrigerants. Evaluate concepts for active capacity control. Continue laboratory experimentation on non-azeotropic refrigerant mixtures. Characterize fluid heat and mass transfer properties.
	Novel Cycles	Evaluated novel cycles and concepts for improved efficiency of refrigeration systems and heat pumps. Selected systems for further in-depth evaluation. One candidate; isothermal Stirling cycle.	Continue evaluation of novel cycles and alternative concepts for heat pumps and refrigeration systems. Identify candidate concepts for further evaluation. Initiate testing of isothermal heat exchanger for Stirling cycle.

BUILDING AND COMMUNITY SYSTEMS
KEY ACTIVITY SUMMARY

PROGRAM AREA OBJECTIVE	KEY ACTIVITY	FY 1983 ACTUAL ACTIVITIES	FY 1984 ESTIMATED ACTIVITIES
	Appliance Technology	Continued test of heat pump water heater to develop a design computer algorithm. Recommended component modifications for advanced systems. Continued research and test of advanced insulation for appliances. Developed supporting theory and heat transfer correlations.	Complete heat pump water heating computer model. Transfer technology. Continue test and evaluation of advanced insulation concepts. Develop technology transfer transfer.
TOTAL, REFRIGERATION SYSTEMS AND APPLIANCES		4500K	3900K

BUILDING AND COMMUNITY SYSTEMS
KEY ACTIVITY SUMMARY

15 NOV 1983

PROGRAM AREA OBJECTIVE	KEY ACTIVITY	FY 1983 ACTUAL ACTIVITIES	FY 1984 ESTIMATED ACTIVITIES
LIGHTING Objective To advance generic technologies for use in advanced lamps and solving lighting problems and to develop basic data on the potential impacts of high efficiency lighting. (Program managed by Lawrence Berkeley Laboratory)	Lamp Technology	Developed experimental gas isotope lamp, conducted experiments to identify efficient isotope mixtures. Initiated proof-of-concept analysis of Zeeman effect on gas plasma. Developed isotope separation process prototype reactor and researched novel gas mixtures.	Evaluate Zeeman effect on lamp types for optimum efficiency. Expand prototype development of isotope separation reactor.
		No Activity	Initiate diagnostic research of gas discharge phenomena.
		Initiated research on the development of electrodeless gas discharge lamps (HID & fluorescent).	Initiate proof of concept of electrodeless, low pressure gas discharge metal lamp.
		No Activity	Characterize electrodeless lamp parameters and examine novel lamp gases in electrodeless gas discharge lamps.
		Studied additional light sources for high frequency operation to analyze system effects. Completed performance characterization of advanced light bulbs and ballasts.	Analyze light source types and determine optimum operating frequency.
		Tested EMI measuring devices and validated EMI test procedures.	Complete development, of EMI measuring device and establish EMI test procedures.
		No Activity	Investigate magnetic materials for phosphors and investigate two photon phosphors.

BUILDING AND COMMUNITY SYSTEMS
KEY ACTIVITY SUMMARY

PROGRAM AREA OBJECTIVE	KEY ACTIVITY	FY 1983 ACTUAL ACTIVITIES	FY 1984 ESTIMATES ACTIVITIES
	System Integration	Developed lighting controls computer program including daylighting. Conducted photocell placement experiments for lighting control.	Analyse lighting control photocell placement with variable fenestration and test chamber orientation. Transfer results to industry.
		Evaluated lighting system components and initiate development of advanced lighting design manuals.	Continue development of advanced lighting design manual and develop design algorithms.
		No Activity	Investigate the interaction of lighting systems with HVAC and envelope systems.
	Performance and Health Impacts	Assessed significant factors in visibility models related to performance. Investigated vision phenomena and developed color photomery model.	Analyze CIE 19/2 visibility model and design experiments to validate relationship between visibility and performance.
		Conducted visual fatigue experiments for visual display terminals.	Collect experimental data on fatigue with visual display terminals.
		Conducted qualitative experiments on the human health effects on lighting.	Complete qualitative experiments on the human health effects of lighting and design experiments to study the quantitative factor of identified health effects.

TOTAL LIGHTING	200K	190K
TOTAL TECHNOLOGY AND CONSUMER PRODUCTS (BUILDING EQUIPMENT)	10,600	10,000

APPENDIX B

503/GRI

PROJECT AREA SUMMARY

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: RESIDENTIAL HEATING SYSTEMS (4.1.1)

Strategic Objectives Supported: (1) Develop Efficient Space Conditioning Equipment and Gas Appliances; (2) Develop Low-Cost Retrofit Conservation Technologies.

Tactical Objective: To develop high-efficiency, gas-fired residential space conditioning devices having low emissions, a minimum first-cost premium, and low cycle cost for both new and replacement markets.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	600	2,200	2,100	2,200	2,200	2,100
Government Funds	0	0	0	0	0	0
Industry Funds	300	600	400	450	450	400

Continuing 1984 Projects:	CY 1984 Funding Estimate			
	GRI	Gov	Ind	Contractor
Pulse Space Heater (089) Develop a compact, high-efficiency unit space heater with very low first cost.	100	0	50	A.G.A. Labs
Condensing Systems/Advanced Heat Exchangers (332) Develop low-cost heat exchanger and condensing technologies for high-efficiency equipment.	200	0	200	*
Spot Heater (424) Develop a low-cost spot/area heater.	500	0	100	*
New 1984 Projects:				
Retrofit and Advanced Space Conditioning Systems (420) Identify, assess, and evaluate residential space/spot heating concepts.	200	0	0	*
Microprocessor Controls Development (421) Apply newly developed vented/unvented sensor/controls to residential heating systems.	300	0	0	*
Advanced Space Heater (422) Develop advanced low-cost ignition and control systems for space heating.	200	0	50	*
Hydronic System Improvement (423) Develop a high-efficiency (93%), low-mass, hydronic heating system.	700	0	200	*

To be determined.

GRI/303

PROJECT AREA SUMMARY

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: COMMERCIAL HEATING SYSTEMS (4.1.2)

Strategic Objectives Supported: (1) Develop Efficient Space Conditioning Equipment and Gas Appliances; (2) Develop Low-Cost Retrofit Conservation Technologies.

Tactical Objective: To develop high-efficiency, low-emission, and economical gas space conditioning devices for application in both new and replacement commercial markets.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	900	1,000	1,400	2,100	2,100	1,800
Government Funds	100	0	0	0	0	0
Industry Funds	0	350	350	400	400	400

Continuing 1984 Projects:	CY 1984 Funding Estimate GRI	Gov	Ind	Contractor
Advanced Furnace Concepts (090) Develop advanced furnace concepts and assess technical barriers to and cost benefits for high-efficiency furnace systems.	300	0	150	*
Pulse Combustion Furnace Systems (333) Develop methodology for design and application of pulse combustion systems.	300	0	150	*
Advanced Heating Systems—Construction (334) Develop new total heating system designs for commercial buildings.	200	0	50	*
New 1984 Projects:				
Retrofit and Advanced Space Conditioning Systems (434) Identify, assess, and evaluate advanced commercial space conditioning systems.	200	0	0	*

*To be determined.

304/GRI

PROJECT AREA SUMMARY

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: RESIDENTIAL HEAT PUMPS AND PRIME MOVERS (4.1.3)

Strategic Objective Supported: Develop Efficient Space Conditioning Equipment and Gas Appliances.

Tactical Objective: To develop highly efficient, reliable, and cost-effective gas-fired heat pumps for residential application.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	5,800	5,100	6,300	6,500	6,600	6,000
Government Funds	0	0	0	0	0	0
Industry Funds	1,581	1,602	2,000	2,000	2,100	1,500

Continuing 1984 Projects:	CY 1984 Funding Estimate			
	GRI	Gov	Ind	Contractor
Absorption Heat Pump (083) Develop a gas-fired heat pump system using advanced absorption technology.	1,600	0	700	*
Stirling/Rankine Heat Pump (084) Develop and evaluate a gas-fired heat pump driven by a free-piston Stirling engine.	1,800	0	902	*
Application and System Performance Analysis (362) Assess residential gas-fired heat pump concepts and components to determine their performance levels for specific applications.	150	0	0	*
IC Engine Analysis and Development (417) Analyze and develop a gas-fired residential heat pump based on internal-combustion technology.	800	0	0	*
Manufacturer Cost Analysis (418) Provide objective manufacturing cost estimates for all gas-fired heat pump developments not having manufacturer involvement.	300	0	0	*
New 1984 Projects:				
Compressor Development (419) Continue or initiate development of compressor technology suitable for integration in gas-fired heat pump systems.	450	0	0	*

*To be determined.

PROJECT AREA SUMMARY

GRI/305

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: COMMERCIAL HEAT PUMPS AND PRIME MOVERS (4.1.4)

Strategic Objective Supported: Develop Efficient Space Conditioning Equipment and Gas Appliances.

Tactical Objective: To develop highly efficient, cost-effective gas-fired heat pumps for use in commercial applications.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	5,500	5,650	7,000	6,500	5,600	5,500
Government Funds	0	0	0	0	0	0
Industry Funds	1,500	1,150	2,000	1,500	1,100	1,000

Continuing 1984 Projects:	CY 1984 Funding Estimate GRI	Gov	Ind	Contractor
Brayton/Rankine Heat Pump (085) Develop a commercial-size gas-fired heat pump that incorporates a Brayton cycle prime mover.	3,400	0	1,000	*
Kinematic Stirling/Rankine Heat Pump (364) Develop a commercial-size, gas-fired heat pump that incorporates a kinematic Stirling prime mover.	1,000	0	150	*
Manufacturer Cost Analysis (441) Provide objective cost estimates for all gas-fired heat pump developments not having manufacturer involvement.	300	0	0	*
New 1984 Projects:				
I.C. Engine/Heat Pump Development (442) Analyze and develop a gas-fired commercial-size heat pump based on internal-combustion technology.	800	0	0	*
Application and Performance Analysis (443) Assess commercial gas-fired heat pump concepts and components to determine their performance levels for specific applications.	150	0	0	*

*To be determined.

306/GRI

PROJECT AREA SUMMARY

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: RESIDENTIAL APPLIANCES (4.1.5)

Strategic Objectives Supported: (1) Develop Efficient Space Conditioning Equipment and Gas Appliances; (2) Develop Low-Cost Retrofit Conservation Technologies.

Tactical Objective: To develop residential gas appliances that demonstrate lower life-cycle costs, improved overall efficiency, more desirable emission characteristics, and increased consumer utility.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	4,400	3,600	4,700	4,550	4,500	4,300
Government Funds	0	0	0	0	0	0
Industry Funds	900	500	700	700	675	650

Continuing 1984 Projects:	CY 1984 Funding Estimate GRI	Gov	Ind	Contractor
Advanced Water Heater Concepts (101) Develop and test new water heater designs using advanced concepts to achieve high annual efficiencies.	300	0	100	•
Environmental Control of Improved Gas Appliances (103) Assess the environmental impact of improved gas appliances, relative to applicable regulatory environmental emissions standards.	200	0	25	•
Performance Analyses of Advanced Gas Burner Systems (104) Develop improved analytical methods for predicting performance and emission characteristics for advanced residential gas burner designs.	300	0	50	Science Applications, Inc.
Integrated Water Heater (111) Develop concepts and determine feasibility of new integrated appliance systems.	250	0	25	•
Residential Cooking Equipment (264) Develop and field-test a residential gas range with improved energy utilization, reduced emissions, and performance with operation comparable to competitive units.	300	0	50	•
Pulse Combustion Technology Advancement (336) Develop methodology for design and application of pulse combustion appliances.	150	0	0	•
Corrosion/Heat Exchangers (337) Correlate the effects of corrosion on appliance efficiency and life.	300	0	0	•
Residential Appliance Technology Advancement (338) Enhance and disseminate advanced technologies to facilitate widespread application.	200	0	0	•
New 1984 Projects:				
Residential Laundry Equipment (428) Develop and field-test prototype residential clothes drying systems to reduce energy consumption and improve performance.	350	0	50	•

GRI/307

New 1984 Projects:	CY 1984 Funding Estimate			
	GRI	Gov	Ind	Contractor
Improved Controls for Residential Appliances (429) Develop advanced ignition and control systems for application to a variety of residential appliances.	150	0	50	*
Low-Cost Residential Water Heater (430) Develop and field-test prototype residential water heaters with improved annual efficiencies at minimum cost premiums.	350	0	50	*
Integrated Water Heater/Space Conditioner (431) Develop and field-test prototype packaged water heating/space conditioning concepts for residential housing.	450	0	50	*
Low NO_x Range Development (432) Develop and field-test residential gas ranges with reduced NO_x and other emissions from both range-top and oven burners.	300	0	50	*

*To be determined.

398/GRI

PROJECT AREA SUMMARY

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: COMMERCIAL APPLIANCES (4.1.6)

Strategic Objective Supported: Develop Efficient Space Conditioning Equipment and Gas Appliances.

Tactical Objective: To develop gas appliance technology for commercial sector featuring improved overall efficiency, more desirable emission characteristics, and increased cost effectiveness.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	2,600	2,400	2,350	2,350	2,150	1,600
Government Funds	100	0	0	0	0	0
Industry Funds	390	550	500	500	450	450

Continuing 1984 Projects:	CY 1984 Funding Estimate GRI	Gov	Ind	Contractor
Commercial Cooking Equipment Improvement (100) Develop and test new concepts for improving efficiency of variety of commercial cooking equipment.	400	0	100	*
Solar/Gas Commercial Water Heater (145) Characterize, develop, and test new solar/gas water heater designs for improving the solar and gas seasonal efficiencies.	200	0	50	*
Commercial Integrated Appliances (265) Develop high-efficiency integrated commercial appliances.	300	0	75	*
Advanced Commercial Water Heater (437) Develop and field-test prototype commercial water heaters using advanced concepts to achieve high annual efficiencies with minimum emissions.	300	0	75	*
New 1984 Projects:				
Commercial Appliance Technology Advancement (435) Enhance and disseminate advanced technologies in order to facilitate widespread application.	200	0	0	*
Low-Cost Water Heater (436) Develop and field-test prototype commercial water heaters with improved annual efficiencies at minimum cost premiums.	300	0	75	*
Advanced Commercial Cooking Concepts (438) Develop advanced design commercial cooking equipment for optimum efficiency and performance.	350	0	100	*
Advanced Commercial Control Systems (439) Develop advanced ignition and control systems for application to a variety of commercial appliances.	150	0	50	*
Performance Analysis of Commercial Burner Systems (440) Develop improved analytical methods for predicting performance and emission characteristics for advanced commercial gas burner designs.	200	0	25	*

*To be determined.

PROJECT AREA SUMMARY

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: COOLING SYSTEMS (4.1.7)

Strategic Objective Supported: Develop Efficient Space Conditioning Equipment and Gas Appliances.

Tactical Objective: To develop low-cost, efficient gas-fired and heat-driven dehumidification and cooling technology for residential/commercial applications.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	1,700	1,900	2,700	3,300	3,900	4,250
Government Funds	100	100	100	150	150	150
Industry Funds	300	700	800	1,200	1,500	1,700

Continuing 1984 Projects:	CY 1984 Funding Estimate			
	GRI	Gov	Ind	Contractor
Advanced Desiccant Cooling Systems (272) Develop and evaluate an advanced solar/gas desiccant system with a cooling COP of 1.2.	1,100	0	400	*
Desiccant Dehumidifier (444) Assess and develop a desiccant dehumidifier for use with passive solar sensible cooling techniques.	100	100	50	*
Gas-Fired Chiller Improvements (445) Develop evolutionary cost and performance improvements to double-effect chiller technology including optimization for integration with gas reciprocating engines.	200	0	100	*
Hybrid Desiccant/Chiller System (446) Assess commercial sector latent and sensible cooling needs and develop a low-cost packaged desiccant/chiller system that provides comfort with reduced energy costs.	500	0	150	*

*To be determined.

5191GRI

PROJECT AREA SUMMARY

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: BUILDING/SYSTEM PERFORMANCE (4.1.8)

Strategic Objectives Supported: (1) Develop Efficient Space Conditioning Equipment and Gas Appliances; (2) Develop Low-Cost Retrofit Conservation Technologies.

Tactical Objective: To define and evaluate parameters important in operation of gas equipment in building structures, and to develop techniques for optimizing gas system/building performance to provide comfort at minimum cost.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	900	1,100	1,200	1,300	1,500	1,900
Government Funds	50	400	400	400	400	400
Industry Funds	80	150	200	250	300	350

Continuing 1984 Projects:	CY 1984 Funding Estimate GRI	Gov	Ind	Contractor
Gas-Fired Heating/Cooling System Analysis (097) Develop improved analytical models for simulating gas furnace and gas heat pump performance.	100	300	100	*
Multi-Family Dwellings and Commercial Structures (262) Determine most energy-efficient application of gas space conditioning equipment for commercial, institutional and multi-family buildings.	100	0	0	*
Passive Solar/Gas Technology Development (148) Characterize performance of gas-fired heating and cooling systems in conjunction with passive buildings techniques, and input space conditioning project areas for equipment development.	400	100	50	*
New 1984 Projects:				
Energy Research House 1 and 2 (425) Plan, purchase, and build Research Houses.	200	0	0	*
Advanced Energy Distribution Systems (426) Develop advanced energy distribution systems for new construction and retrofit applications.	200	0	0	*
Co-Heating Seasonal Performance Assessment (427) Determine operating parameters for optimizing co-heating residential structures.	100	0	0	*

*To be determined.

PROJECT AREA SUMMARY

GRI/31

4.0 **Efficient Utilization**

4.1 **Residential/Commercial Energy Systems**

Project Area: **PHOSPHORIC ACID FUEL CELLS (4.1.9)**

Strategic Objective Supported: **Develop Advanced Energy Utilization Systems.**

Tactical Objective: **To obtain field verification of the performance and maintenance characteristics of phosphoric acid onsite fuel cell energy systems and, through technology advancements, to bring onsite fuel cell energy service to the point of application at the earliest practical date.**

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	19,550	19,050	5,534	2,150	2,150	1,500
Government Funds	3,989	3,730	1,180	0	0	0
Industry Funds	8,600	4,000	0	0	0	0

Continuing 1984 Projects:	CY 1984 Funding Estimate GRI	Gov	Ind	Contractor
Manufacture, Fabrication, and Support of Field Test Power Plants (113) Provide for the manufacture, spare parts, manuals, training, and engineering support for the power plants to be used in the field test.	4,787	350	600	United Technologies Corp.
Field Test Support (114) Provide for coordination, management, data analysis installation, electrical and mechanical support, and reporting of field evaluation of 40-kW fuel cells in a variety of applications.	1,063	180	3,400	Science Applications, Inc.; United Technologies Corp.
Onsite Fuel Cell User Group Support (116) Provide administrative and analytical support to the Onsite Fuel Cell Users Group.	200	0	0	*
Technology Development (117) Provide the component technology, systems design, and verification of a fuel cell power plant to meet initial early market entry cost goals.	13,000	3,200	0	United Technologies Corp.

*To be determined.

DYE/GRI

PROJECT AREA SUMMARY

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: ADVANCED FUEL CELL CONCEPTS (4.1.10)

Strategic Objective Supported: Develop Advanced Energy Utilization Systems.

Tactical Objective: To provide the system and technology basis for commercialization of a 50-kW to 1000-kW methane-fueled carbonate fuel cell for use in cogeneration applications.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	0	0	2,100	2,300	2,900	3,000
Government Funds	5,200	2,700	0	0	0	0
Industry Funds	2,200	2,700	3,200	3,700	4,000	5,000

Note: GRI funding for R&D on advanced fuel cell concepts has been deferred until 1985. EPRI and DOE will conduct relevant R&D in 1984 without GRI funding.

PROJECT AREA SUMMARY GRI/313

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: ENERGY COGENERATION SYSTEMS (4.1.11)

Strategic Objective Supported: Develop Advanced Energy Utilization Systems.

Tactical Objective: To develop efficient, cost-effective gas-fired cogeneration systems for multi-family residential, commercial, and industrial applications.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	2,400	3,800	7,500	8,000	9,000	8,800
Government Funds	900	900	200	0	0	0
Industry Funds	750	1,700	1,900	1,900	1,800	1,500

Continuing 1984 Projects:	CY 1984 Funding Estimate GRI	Gov	Ind	Contractor
Cogeneration Systems Development (122) Develop packaged, pre-engineered, gas-fired cogeneration systems for commercial and multifamily applications.	1,400	0	600	*
Gas/Solar Cogeneration (274) Assess, develop, and field-test modular solar-augmented gas-fired cogeneration systems.	400	900	300	*
Cogeneration Storage Concepts (359) Evaluate feasibility of and develop daily thermal storage technologies for cogeneration applications.	200	0	50	*
Ancillary Component Improvements (360) Improve efficiency and/or reduce cost of cogeneration system peripheral components.	450	0	250	*
Prime Mover Advancements (361) Develop evolutionary modifications of prime mover technology which will enhance performance and life and reduce emissions and costs.	800	0	300	*
Compact Heat Recovery (433) Develop compact and efficient heat recovery equipment suitable for commercial applications that is reliable and relatively maintenance free.	550	0	200	*

*To be determined

302/GRI

PROJECT AREA SUMMARY

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: RESIDENTIAL HEATING SYSTEMS (4.1.1)

Strategic Objectives Supported: (1) Develop Efficient Space Conditioning Equipment and Gas Appliances; (2) Develop Low-Cost Retrofit Conservation Technologies.

Tactical Objective: To develop high-efficiency, gas-fired residential space conditioning devices having low emissions, a minimum first-cost premium, and low cycle cost for both new and replacement markets.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	600	2,200	2,100	2,200	2,200	2,100
Government Funds	0	0	0	0	0	0
Industry Funds	300	600	400	450	450	400

Continuing 1984 Projects:

	CY 1984 Funding Estimate			
	GRI	Gov	Ind	Contractor
Pulse Space Heater (089) Develop a compact, high-efficiency unit space heater with very low first cost.	100	0	50	A.G.A. Labs
Condensing Systems/Advanced Heat Exchangers (332) Develop low-cost heat exchanger and condensing technologies for high-efficiency equipment.	200	0	200	*
Spot Heater (424) Develop a low-cost spot/area heater.	500	0	100	*

New 1984 Projects:

Retrofit and Advanced Space Conditioning Systems (420) Identify, assess, and evaluate residential space/spot heating concepts.	200	0	0	*
Microprocessor Controls Development (421) Apply newly developed vented/unvented sensor/controls to residential heating systems.	300	0	0	*
Advanced Space Heater (422) Develop advanced low-cost ignition and control systems for space heating.	200	0	50	*
Hydronic System Improvement (423) Develop a high-efficiency (93%), low-mass, hydronic heating system.	700	0	200	*

To be determined.

PROJECT AREA SUMMARY

GRI/383

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: COMMERCIAL HEATING SYSTEMS (4.1.2)

Strategic Objectives Supported: (1) Develop Efficient Space Conditioning Equipment and Gas Appliances; (2) Develop Low-Cost Retrofit Conservation Technologies.

Tactical Objective: To develop high-efficiency, low-emission, and economical gas space conditioning devices for application in both new and replacement commercial markets.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	900	1,000	1,400	2,100	2,100	1,800
Government Funds	100	0	0	0	0	0
Industry Funds	0	350	350	400	400	400

Continuing 1984 Projects:	CY 1984 Funding Estimate GRI	Gov	Ind	Contractor
Advanced Furnace Concepts (090) Develop advanced furnace concepts and assess technical barriers to and cost benefits for high-efficiency furnace systems.	300	0	150	*
Pulse Combustion Furnace Systems (333) Develop methodology for design and application of pulse combustion systems.	300	0	150	*
Advanced Heating Systems—Construction (334) Develop new total heating system designs for commercial buildings.	200	0	50	*
New 1984 Projects:				
Retrofit and Advanced Space Conditioning Systems (434) Identify, assess, and evaluate advanced commercial space conditioning systems.	200	0	0	*

*To be determined.

384/GRI

PROJECT AREA SUMMARY

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: RESIDENTIAL HEAT PUMPS AND PRIME MOVERS (4.1.3)

Strategic Objective Supported: Develop Efficient Space Conditioning Equipment and Gas Appliances.

Tactical Objective: To develop highly efficient, reliable, and cost-effective gas-fired heat pumps for residential application.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	5,800	5,100	6,300	6,500	6,600	6,000
Government Funds	0	0	0	0	0	0
Industry Funds	1,581	1,602	2,000	2,000	2,100	1,500

Continuing 1984 Projects:	CY 1984 Funding Estimate			
	GRI	Gov	Ind	Contractor
Absorption Heat Pump (083) Develop a gas-fired heat pump system using advanced absorption technology.	1,600	0	700	*
Stirling/Rankine Heat Pump (084) Develop and evaluate a gas-fired heat pump driven by a free-piston Stirling engine.	1,800	0	902	*
Application and System Performance Analysis (362) Assess residential gas-fired heat pump concepts and components to determine their performance levels for specific applications.	150	0	0	*
IC Engine Analysis and Development (417) Analyze and develop a gas-fired residential heat pump based on internal-combustion technology.	800	0	0	*
Manufacturer Cost Analysis (418) Provide objective manufacturing cost estimates for all gas-fired heat pump developments not having manufacturer involvement.	300	0	0	*
New 1984 Projects:				
Compressor Development (419) Continue or initiate development of compressor technology suitable for integration in gas-fired heat pump systems.	450	0	0	*

*To be determined.

PROJECT AREA SUMMARY

GRI/305

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: COMMERCIAL HEAT PUMPS AND PRIME MOVERS (4.1.4)

Strategic Objective Supported: Develop Efficient Space Conditioning Equipment and Gas Appliances.

Tactical Objective: To develop highly efficient, cost-effective gas-fired heat pumps for use in commercial applications.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	5,500	5,650	7,000	6,500	5,600	5,500
Government Funds	0	0	0	0	0	0
Industry Funds	1,500	1,150	2,000	1,500	1,100	1,000

Continuing 1984 Projects:	CY 1984 Funding Estimate GRI	Gov	Ind	Contractor
Brayton/Rankine Heat Pump (085) Develop a commercial-size gas-fired heat pump that incorporates a Brayton cycle prime mover.	3,400	0	1,000	*
Kinematic Stirling/Rankine Heat Pump (364) Develop a commercial-size, gas-fired heat pump that incorporates a kinematic Stirling prime mover.	1,000	0	150	*
Manufacturer Cost Analysis (441) Provide objective cost estimates for all gas-fired heat pump developments not having manufacturer involvement.	300	0	0	*
New 1984 Projects:				
I.C. Engine/Heat Pump Development (442) Analyze and develop a gas-fired commercial-size heat pump based on internal-combustion technology.	800	0	0	*
Application and Performance Analysis (443) Assess commercial gas-fired heat pump concepts and components to determine their performance levels for specific applications.	150	0	0	*

*To be determined.

306/GRI

PROJECT AREA SUMMARY

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: RESIDENTIAL APPLIANCES (4.1.5)

Strategic Objectives Supported: (1) Develop Efficient Space Conditioning Equipment and Gas Appliances; (2) Develop Low-Cost Retrofit Conservation Technologies.

Tactical Objective: To develop residential gas appliances that demonstrate lower life-cycle costs, improved overall efficiency, more desirable emission characteristics, and increased consumer utility.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	4,400	3,600	4,700	4,550	4,500	4,300
Government Funds	0	0	0	0	0	0
Industry Funds	900	500	700	700	675	650

Continuing 1984 Projects:	CY 1984 Funding Estimate			
	GRI	Gov	Ind	Contractor
Advanced Water Heater Concepts (101) Develop and test new water heater designs using advanced concepts to achieve high annual efficiencies.	300	0	100	*
Environmental Control of Improved Gas Appliances (103) Assess the environmental impact of improved gas appliances, relative to applicable regulatory environmental emissions standards.	200	0	25	*
Performance Analyses of Advanced Gas Burner Systems (104) Develop improved analytical methods for predicting performance and emission characteristics for advanced residential gas burner designs.	300	0	50	Science Applications, Inc.
Integrated Water Heater (111) Develop concepts and determine feasibility of new integrated appliance systems.	250	0	25	*
Residential Cooking Equipment (264) Develop and field-test a residential gas range with improved energy utilization, reduced emissions, and performance with operation comparable to competitive units.	300	0	50	*
Pulse Combustion Technology Advancement (336) Develop methodology for design and application of pulse combustion appliances.	150	0	0	*
Corrosion/Heat Exchangers (337) Correlate the effects of corrosion on appliance efficiency and life.	300	0	0	*
Residential Appliance Technology Advancement (338) Enhance and disseminate advanced technologies to facilitate widespread application.	200	0	0	*
New 1984 Projects:				
Residential Laundry Equipment (428) Develop and field-test prototype residential clothes drying systems to reduce energy consumption and improve performance.	350	0	50	*

New 1984 Projects:	CY 1984 Funding Estimate			
	GRI	Gov	Ind	Contractor
Improved Controls for Residential Appliances (429) Develop advanced ignition and control systems for application to a variety of residential appliances.	150	0	50	*
Low-Cost Residential Water Heater (430) Develop and field-test prototype residential water heaters with improved annual efficiencies at minimum cost premiums.	350	0	50	*
Integrated Water Heater/Space Conditioner (431) Develop and field-test prototype packaged water heating/space conditioning concepts for residential housing.	450	0	50	*
Low NO_x Range Development (432) Develop and field-test residential gas ranges with reduced NO_x and other emissions from both range-top and oven burners.	300	0	50	*

*To be determined.

308/GRI

PROJECT AREA SUMMARY

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: COMMERCIAL APPLIANCES (4.1.6)

Strategic Objective Supported: Develop Efficient Space Conditioning Equipment and Gas Appliances.

Tactical Objective: To develop gas appliance technology for commercial sector featuring improved overall efficiency, more desirable emission characteristics, and increased cost effectiveness.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	2,600	2,400	2,350	2,350	2,150	1,600
Government Funds	100	0	0	0	0	0
Industry Funds	390	550	500	500	450	450

Continuing 1984 Projects:	CY 1984 Funding Estimate			
	GRI	Gov	Ind	Contractor
Commercial Cooking Equipment Improvement (100) Develop and test new concepts for improving efficiency of variety of commercial cooking equipment.	400	0	100	*
Solar/Gas Commercial Water Heater (145) Characterize, develop, and test new solar/gas water heater designs for improving the solar and gas seasonal efficiencies.	200	0	50	*
Commercial Integrated Appliances (265) Develop high-efficiency integrated commercial appliances.	300	0	75	*
Advanced Commercial Water Heater (437) Develop and field-test prototype commercial water heaters using advanced concepts to achieve high annual efficiencies with minimum emissions.	300	0	75	*
New 1984 Projects:				
Commercial Appliance Technology Advancement (435) Enhance and disseminate advanced technologies in order to facilitate widespread application.	200	0	0	*
Low-Cost Water Heater (436) Develop and field-test prototype commercial water heaters with improved annual efficiencies at minimum cost premiums.	300	0	75	*
Advanced Commercial Cooking Concepts (438) Develop advanced design commercial cooking equipment for optimum efficiency and performance.	350	0	100	*
Advanced Commercial Control Systems (439) Develop advanced ignition and control systems for application to a variety of commercial appliances.	150	0	50	*
Performance Analysis of Commercial Burner Systems (440) Develop improved analytical methods for predicting performance and emission characteristics for advanced commercial gas burner designs.	200	0	25	*

*To be determined.

PROJECT AREA SUMMARY

GRI/3C

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: COOLING SYSTEMS (4.1.7)

Strategic Objective Supported: Develop Efficient Space Conditioning Equipment and Gas Appliances.

Tactical Objective: To develop low-cost, efficient gas-fired and heat-driven dehumidification and cooling technology for residential/commercial applications.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	1,700	1,900	2,700	3,300	3,800	4,250
Government Funds	100	100	100	150	150	150
Industry Funds	300	700	800	1,200	1,500	1,700

Continuing 1984 Projects:	CY 1984 Funding Estimate GRI	Gov	Ind	Contractor
Advanced Desiccant Cooling Systems (272) Develop and evaluate an advanced solar/gas desiccant system with a cooling COP of 1.2.	1,100	0	400	*
Desiccant Dehumidifier (444) Assess and develop a desiccant dehumidifier for use with passive solar sensible cooling techniques.	100	100	50	*
Gas-Fired Chiller Improvements (445) Develop evolutionary cost and performance improvements to double-effect chiller technology including optimization for integration with gas reciprocating engines.	200	0	100	*
Hybrid Desiccant/Chiller System (446) Assess commercial sector latent and sensible cooling needs and develop a low-cost packaged desiccant/chiller system that provides comfort with reduced energy costs.	500	0	150	*

*To be determined.

210/GRI

PROJECT AREA SUMMARY

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: BUILDING/SYSTEM PERFORMANCE (4.1.8)

Strategic Objectives Supported: (1) Develop Efficient Space Conditioning Equipment and Gas Appliances; (2) Develop Low-Cost Retrofit Conservation Technologies.

Tactical Objective: To define and evaluate parameters important in operation of gas equipment in building structures, and to develop techniques for optimizing gas system/building performance to provide comfort at minimum cost.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	900	1,100	1,200	1,300	1,600	1,900
Government Funds	50	400	400	400	400	400
Industry Funds	60	150	200	250	300	350

Continuing 1984 Projects:	CY 1984 Funding Estimate			
	GRI	Gov	Ind	Contractor
Gas-Fired Heating/Cooling System Analysis (097) Develop improved analytical models for simulating gas furnace and gas heat pump performance.	100	300	100	*
Multi-Family Dwellings and Commercial Structures (262) Determine most energy-efficient application of gas space conditioning equipment for commercial, institutional and multi-family buildings.	100	0	0	*
Passive Solar/Gas Technology Development (148) Characterize performance of gas-fired heating and cooling systems in conjunction with passive buildings techniques, and input space conditioning project areas for equipment development.	400	100	50	*
New 1984 Projects:				
Energy Research House 1 and 2 (425) Plan, purchase, and build Research Houses.	200	0	0	*
Advanced Energy Distribution Systems (426) Develop advanced energy distribution systems for new construction and retrofit applications.	200	0	0	*
Co-Heating Seasonal Performance Assessment (427) Determine operating parameters for optimizing co-heating residential structures.	100	0	0	*

*To be determined.

PROJECT AREA SUMMARY

4.0 **Efficient Utilization**

4.1 **Residential/Commercial Energy Systems**

Project Area: **PHOSPHORIC ACID FUEL CELLS (4.1.9)**

Strategic Objective Supported: **Develop Advanced Energy Utilization Systems.**

Tactical Objective: **To obtain field verification of the performance and maintenance characteristics of phosphoric acid onsite fuel cell energy systems and, through technology advancements, to bring onsite fuel cell energy service to the point of application at the earliest practical date.**

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	19,550	19,050	5,534	2,150	2,150	1,500
Government Funds	3,989	3,730	1,180	0	0	0
Industry Funds	8,600	4,000	0	0	0	0

Continuing 1984 Projects:	CY 1984 Funding Estimate GRI	Gov	Ind	Contractor
Manufacture, Fabrication, and Support of Field Test Power Plants (113) Provide for the manufacture, spare parts, manuals, training, and engineering support for the power plants to be used in the field test.	4,787	350	600	United Technologies Corp.
Field Test Support (114) Provide for coordination, management, data analysis installation, electrical and mechanical support, and reporting of field evaluation of 40-kW fuel cells in a variety of applications.	1,063	180	3,400	Science Applications, Inc.; United Technologies Corp.
Onsite Fuel Cell User Group Support (116) Provide administrative and analytical support to the Onsite Fuel Cell Users Group.	200	0	0	*
Technology Development (117) Provide the component technology, systems design, and verification of a fuel cell power plant to meet initial early market entry cost goals.	13,000	3,200	0	United Technologies Corp.

*To be determined.

312/GRI

PROJECT AREA SUMMARY

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: ADVANCED FUEL CELL CONCEPTS (4.1.10)

Strategic Objective Supported: Develop Advanced Energy Utilization Systems.

Tactical Objective: To provide the system and technology basis for commercialization of a 50-kW to 1000-kW methane-fueled carbonate fuel cell for use in cogeneration applications.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	0	0	2,100	2,300	2,900	3,000
Government Funds	5,200	2,700	0	0	0	0
Industry Funds	2,200	2,700	3,200	3,700	4,000	5,000

Note: GRI funding for R&D on advanced fuel cell concepts has been deferred until 1985. EPRI and DOE will conduct relevant R&D in 1984 without GRI funding.

PROJECT AREA SUMMARY GRI/313

4.0 Efficient Utilization

4.1 Residential/Commercial Energy Systems

Project Area: ENERGY COGENERATION SYSTEMS (4.1.11)

Strategic Objective Supported: Develop Advanced Energy Utilization Systems.

Tactical Objective: To develop efficient, cost-effective gas-fired cogeneration systems for multi-family residential, commercial, and industrial applications.

Budget ($1000)

Calendar Year	1983	1984	1985	1986	1987	1988
GRI Funds	2,400	3,800	7,500	8,000	9,000	8,800
Government Funds	900	900	200	0	0	0
Industry Funds	750	1,700	1,900	1,900	1,800	1,500

Continuing 1984 Projects:	CY 1984 Funding Estimate			
	GRI	Gov	Ind	Contractor
Cogeneration Systems Development (122) Develop packaged, pre-engineered, gas-fired cogeneration systems for commercial and multifamily applications.	1,400	0	600	*
Gas/Solar Cogeneration (274) Assess, develop, and field-test modular solar-augmented gas-fired cogeneration systems.	400	900	300	*
Cogeneration Storage Concepts (359) Evaluate feasibility of and develop daily thermal storage technologies for cogeneration applications.	200	0	50	*
Ancillary Component Improvements (360) Improve efficiency and/or reduce cost of cogeneration system peripheral components.	450	0	250	*
Prime Mover Advancements (361) Develop evolutionary modifications of prime mover technology which will enhance performance and life and reduce emissions and costs.	800	0	300	*
Compact Heat Recovery (433) Develop compact and efficient heat recovery equipment suitable for commercial applications that is reliable and relatively maintenance free.	550	0	200	*

*To be determined.

APPENDIX C

EPRI

RESIDENTIAL AND COMMERCIAL PROGRAM

PROGRAM OVERVIEW AND PROJECT DESCRIPTIONS

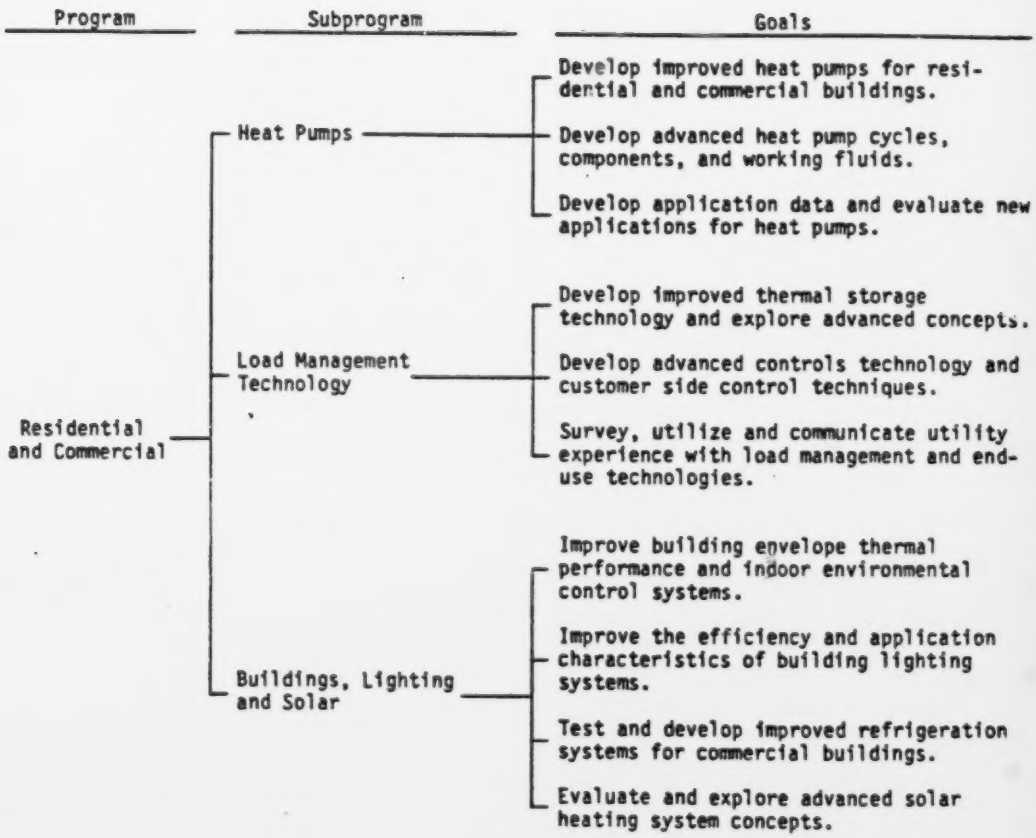
MAY 1983

PROGRAM MANAGER

ARVO LANNUS

ELECTRIC POWER RESEARCH INSTITUTE

APPENDIX C


Program
Subprogram
Goals
Residential and Commercial
Heat Pumps
Develop improved heat pumps for residential and commercial buildings.
Develop advanced heat pump cycles, components, and working fluids.
Develop application data and evaluate new applications for heat pumps.
Load Management Technology
Develop improved thermal storage technology and explore advanced concepts.
Develop advanced controls technology and customer side control techniques.
Survey, utilize and communicate utility experience with load management and end-use technologies.
Buildings, Lighting and Solar
Improve building envelope thermal performance and indoor environmental control systems.
Improve the efficiency and application characteristics of building lighting systems.
Test and develop improved refrigeration systems for commercial buildings.
Evaluate and explore advanced solar heating system concepts.

Residential and Commercial Program Logic

Energy Management & Utilization
Division

PROGRAM Residential & Commercial

MANAGER Lennus, Arvo

PRINCIPAL CONTENT * Heat pumps, load management and control technology, commercial cool storage, heat storage, utility conservation/load management, building, lighting, refrigeration and solar systems.

MAJOR CHANGES * More focussed in heat pump and load control system technologies; reduced advanced thermal storage and solar heating/cooling.

MAJOR PROJECTS

Heat Pump Analysis, Testing and Development

PLANNED EXPENDITURES ($ Millions)

SUBPROGRAM	1984	1985	1986	1987	1988	TOTAL 84-88
Heat Pumps	2.5	2.9	3.5	4.3	5.5	18.7
Buildings, Lighting & Solar	1.3	1.3	1.4	1.3	1.5	6.8
Load Management Technology	1.9	2.1	2.5	2.7	3.1	12.3
TOTAL - RESIDENTIAL & COMMERCIAL	5.7	6.3	7.4	8.3	10.1	37.8

PROGRAM DESCRIPTION

The Residential and Commercial Program has two major thrusts. The program seeks to provide utilities with a technical information base, verified by laboratory or field measurements, on the performance of selected end-use technologies; and with improved methods of end-use system application, performance prediction and evaluation. In parallel, the program is undertaking the development of improved energy end-use technologies--especially heat pumps, thermal storage, and control systems for load management. These technologies can have a significant impact on the existing building stock and are capable of replacing end-use systems using fossil fuels. Properly designed, deployed and controlled, they can result in improved load characteristics for utilities while reducing energy costs for their customers.

The major specific objectives for the current planning period are to:

- Develop central heat pumps with improved efficiency, better load characteristics and broader applicability to existing as well as new buildings (1987).
- Develop room heat pumps with improved efficiency and application characteristics in cold climates (1986-88).
- Develop advanced heat pumps for commercial and multifamily building applications to offer improved efficiency and demand management options (1986-88).
- Develop improved techniques for engineering and control of commercial cool storage systems (1986-88).
- Develop techniques and controls for energy-efficient and cost-effective customer-side load management (1986).
- Evaluate effect of infiltration and of weatherization measures on energy use and indoor air quality in residential buildings (1984-85).
- Develop improved design and application procedures for building lighting systems (1985).

IMPORTANCE OF THE PROGRAM

The residential and commercial sectors together account for about 36% of the energy and 60% of the electricity consumption in the United States. Residential electric space heating and cooling and water heating, and commercial/industrial space cooling, lighting and refrigeration, represent the major uses of electric energy in buildings. These energy uses are primarily responsible for the pronounced summer and winter peaks of electric utilities, yet are least able to bear the cost of

capital-intensive investments to save energy and reduce demand.

As in previous years, the principal emphasis of the program is in the residential sector. Residential customers present utilities with their most severe challenges and most immediate research needs. About 50% of the new single-family homes in the U.S. are electrically heated, with 25-30% of the new homes being heated by electric heat pumps. Nearly two-thirds of all new residential buildings are electrically air-conditioned, a market trend over which utilities have little control. These factors and the potential for retrofit emphasize the importance of the Program's efforts to increase efficiency and reduce peak demand of heat pumps.

In this planning period, emphasis on buildings-related research targeted at commercial and industrial sector customers will continue to grow. Commercial customers present utilities with a market for energy and services which is only now beginning to be tapped, as well as with immediate opportunities for system load factor improvement through load management. For example, EPRI's studies have shown that 25-40% of the summertime peak demand of utilities is due to commercial customers. Moreover, only 4% of those customers--mostly large office and institutional buildings and department stores--contribute almost half of the commercial cooling demand. Research that addresses the need for those customers to reduce their peak loads and shift some of their energy usage to off-peak periods offers immediate benefits to utilities as well as their customers.

Lighting has been estimated to account for 20-25% of the total electricity use in the U.S. and as much as 25-40% of the peak demand of commercial office buildings. Reduction in lighting demand by use of more efficient equipment and by effective daylight integration would have the immediate effect of reducing cooling demand as well. EPRI research in this area can develop equipment and methods for more effective utilization and integration of building lighting systems.

Refrigeration, a new research area for this program, is the third largest commercial electrical load. For many utilities, especially those serving largely suburban areas, commercial buildings with large refrigeration loads (e.g., supermarkets) represent a significant and growing fraction of their total commercial load and an important component of their overall market. EPRI studies have shown that the demand of supermarkets and other food sales facilities is coincident with the summer peak demand of many utilities. Therefore, these customers offer an important target for utilities' end-use programs.

The Residential and Commercial Program will continue to screen and selectively explore new end-use technology concepts and to develop data and methods for utilities to use in evaluating end-use technologies for their customers. The program will also work jointly with HVAC, controls and other equipment manufacturers to identify, accelerate the development, and assist

in the commercialization of technologies of special importance to utilities and their customers.

Key results of the Program's R&D will be made available to member utilities in the form of design guidelines, manuals, and seminars, through the formation of users groups and by undertaking joint demonstrations, with individual utilities, of advanced end-use equipment.

SUBPROGRAM STRUCTURE

The Residential and Commercial Program is organized into the following three subprograms:

1. Heat Pumps Subprogram

This subprogram seeks to develop broadly applicable heat pumps that combine improved seasonal performance and efficiency with more favorable utility load characteristics. Development of equipment with broader retrofit applicability to existing buildings is also an important aspect. The principal goals of this subprogram are to:

- Develop a central heat pump with improved economics and efficiency, improved power demand characteristics in the heating and cooling modes, and greater flexibility for multizone and retrofit applications.
- Develop a room heat pump with improved efficiency and load characteristics (especially at low ambient temperatures), improved applicability in cold climates and significantly reduced noise levels.
- Develop and test improved design and control procedures for water-loop heat pumps for commercial applications and improve the efficiency of equipment used in water loop systems.
- Seek further increases in heat pump performance through development of advanced technology.

The nearer-term strategy of the subprogram is to continue improvement of vapor-compression-cycle air source heat pumps and to broaden applications of heat pumps capable of utilizing ground, well water, surface water and internal heat sources as well as waste or stored heat.

In the 1984-88 time period, major efforts will concentrate on developing central heat pumps for residential and small commercial buildings with warm air distribution systems as well as room (or single-zone) heat pumps for single-family home retrofit and multifamily apartment applications. The targets for these development are shown in Table I.

TABLE I. Performance Targets for Central and Room Heat Pump Development

	Central Heat Pump	Room Heat Pump
Heating efficiency	30% improvement in HSPF	25% improvement in HSPF
Cooling efficiency	SEER 14 or better	EER 9 or better
Power demand	Heating demand reduced by 2 kW	Heating demand reduced by 1 kW
	Cooling demand limit	Reduced cooling demand
Noise	Reduced outdoor sound levels	Reduced indoor and outdoor noise
Reliability	Improved defrost, reduced cycling	
Controls	Set-back, load management capability	Set-back, load management capability
Zone control	Multizone (as option)	Single- or dual-zone

Supporting the equipment and systems development activities described above is a program of applications research to evaluate the performance of heat pump water heaters, develop and validate improved methods of system performance estimation, and field test equipment which is being commercially introduced and represents novel technical approaches to performance improvement. Examples are bivalent heat pumps for add-on to oil or gas furnaces, and dual-capacity modulating systems. Research and testing of large central-plant heat pump systems for commercial and industrial buildings will be initiated in this planning period, and community-wide applications of heat pumps using waste heat and other energy sources will be explored.

Advanced concepts will be investigated for their potential to achieve major improvements and broader applications of heat pumps in the longer term. Examples include non-vapor-compression cycles for specialty applications, nonazeotropic working fluids, hermetically sealed variable-speed motors for heat pumps, as well as other control, heat exchange and compressor component improvements. As these promising new approaches are evaluated and tested, heat pump systems projects will be undertaken to integrate, demonstrate and commercialize these advances.

2. Load Management Technology Subprogram

This subprogram supports development of technology that provides residential and commercial customers with cost-effective options to control their electricity consumption patterns in a manner consistent with utility load management objectives. The principal goals of the subprogram are to:

- Develop improved engineering design procedures, control methods and equipment for thermal storage systems, with emphasis on the commercial building application.
- Develop control techniques and equipment to perform local load management functions in a manner adapted to the customer's preferences and consistent with utility objectives.
- Collect, integrate and communicate information and results from utility-sponsored load management, conservation and solar end-use projects.

Basic technology for both heat and cool storage load management systems is available. However, widespread implementation of commercial cool storage systems--the most important goal--is hampered by lack of proven design methods, inadequate understanding of factors affecting system performance, and the attendant overdesign, operating problems, and increased costs. In the 1984-88 time frame, research efforts will concentrate on developing engineering and control techniques designed for installation of systems at little or no cost premium above conventional air conditioning. This implies a cost target

of $50-70/ton-hour for the storage subsystem compared to current costs of $80-200/ton-hour. For chilled water and ice systems, costs will be reduced through development of more effective stratification techniques and by improved design of water tanks, ice storage and refrigeration subsystems. Physical and engineering models will be developed to guide system sizing and design of controls to fully integrate storage into the building's HVAC system.

In the heat storage area, the aim will be to lower the first cost by substituting less expensive storage materials for the ceramic bricks now in use. Design, development and testing of a system using crushed rocks is expected to reduce the current installed cost from more than $5,000 to $2,500-4,000 for a nominal 200 kWh(th) storage furnace. This would extend the central residential and commercial storage heating market to areas with less severe heating requirements. If available at the lower end of the cost scale, such a system would offer an immediate payback relative to an oil furnace and a 1-2 year payback on conventional electric heating in regions with lower-cost off-peak electricity.

Most of the utility load management activities to date have been limited to direct control of residential air conditioners and water heaters. The potential to achieve other load management objectives more closely adapted to the customer's preferences remains largely unexplored. Accordingly, research will be directed at identifying effective local and distributed control techniques and developing the requisite controls, exploiting the latest advances in microprocessor technology. Other planned work includes design and implementation of field tests to systematically evaluate algorithms and equipment concepts for residential energy management systems; review and development of improved commercial load management techniques; and development of selected control system components such as sensors, switches, local communication and load-monitoring equipment.

Research results will be disseminated primarily through licensing of proven methods and designs, and in the form of manuals, workshops, and seminars. In addition, information will continue to be compiled on utility programs. In-depth technology reviews will be carried out to integrate and disseminate utility findings on end-use technologies. Additional data acquisition and analysis, targeted to fill technical and economic data gaps, will be undertaken jointly with utilities. Cooperation with the Demand and Conservation Program will be sought in areas requiring impact analyses.

3. Buildings, Lighting and Solar Subprogram

This subprogram is designed to develop and validate an integrated approach to sizing and design of building HVAC, lighting, refrigeration, and other energy-using systems for optimum occupant comfort, productivity and building energy efficiency. The principal goals of this subprogram are to:

- Develop an integrated approach to sizing, applying and predicting the performance of building lighting, HVAC, refrigeration and indoor environmental control systems and their interaction with the building energy system.
- Develop and verify improved models as well as design and retrofit practices for building ventilation to maintain comfort, energy efficiency and indoor air quality.
- Verify, improve and maintain the methods of conventional and solar end-use system simulation.
- Develop methods and components for improvement of the efficiency of lighting systems and controls including methods of daylight integration into commercial/industrial building lighting systems.

This requires an improved understanding of the performance of the thermal envelope of the building, its interactions with the atmospheric environment and with the ground, and of the interrelationships among infiltration/ventilation, energy use, indoor air quality and occupant comfort. The activities required to establish these relationships will be conducted jointly with the Environmental Physics and Chemistry Program of the Energy Analysis and Environment Division.

The evaluation of the effectiveness of building energy conservation retrofit measures and the development of methods for their analysis and monitoring is being continued.

An adequate information base does not exist on the thermal effects of lighting systems to permit a design approach integral with HVAC systems for reduction of peak demand and energy use. Accordingly, the subprogram will investigate effective methods of integrating daylighting and building lighting systems and develop the required controls and sensors. Also, selected efforts to improve the efficiency of lamps, ballasts and other lighting system components will be undertaken. Methods of estimating the interaction between building lighting and HVAC systems will be developed to assist in the integrated design of energy-efficient buildings and work places.

The principal results of these investigations will be disseminated to the utility industry in the form of design procedures and manuals for improved HVAC, lighting system and building design or retrofit.

Research is being initiated in this planning period on efficient commercial refrigeration systems and their applications. Monitoring and analysis of selected supermarkets will be undertaken to develop data on the demand characteristics, and concepts such as mechanical subcooling and desiccant dehumidification for improvement of energy efficiency will be tested. In parallel, refrigeration systems and components with improved "turndown" capability and overall efficiency will be tested as possible substitutes for the conventional supermarket refrigeration system.

Demonstrations of active residential and commercial solar space conditioning systems have been concluded and the results are being disseminated to utilities. One output of this work is a computer simulation methodology and software (EMPS 1.0) for undertaking analyses of solar heating and cooling systems in individual utilities' service territories. The main focus of solar heating and cooling research will now be to assist utilities in the use of EPRI's methods for analysis of system impacts, and the maintenance of an evaluation capability. However, passive/hybrid solar cooling/dehumidification methods for humid regions and cost-reduction approaches to active solar system components will be explored in limited efforts.

Program RESIDENTIAL AND COMMERCIAL

SUBPROGRAM Goal o Key Events 1984 Performance Milestones	Key Event Timing 1984	1985	1986	After 1986
HEAT PUMPS				
Develop improved heat pumps for residential and commercial buildings.				
o Develop engineering prototype advanced central heat pump.			•	
o Field test advanced central heat pump.				•
Develop advanced heat pump cycles, components and working fluids.				
o Evaluate concept of advanced heat pump with nonazeotropic working fluids.			•	
o Complete tests of scavenge cycle/speed modulated heat pump.			•	
o Complete dynamic control development.			•	
Develop application data and evaluate new applications for heat pumps.				
o Develop performance analysis and application guidelines for multizone vs. centrally controlled heating/cooling systems.			•	
LOAD MANAGEMENT TECHNOLOGY				
Develop improved thermal storage technology and explore advanced concepts.				
o Develop and validate commercial cool storage engineering and control techniques.				•
o Develop and test prototype lower-first-cost heat storage system.				•
Develop controls technology and customer-side control techniques.				
o Develop test package for field evaluation of residential energy management systems concepts.			•	
o Issue guide on commercial load management techniques.				•
Survey and integrate utility experience with load management and end-use technologies.				
o Issue review of utility findings with selected end-use technologies.			•	

33-482 O - 84 - 12

Program RESIDENTIAL AND COMMERCIAL (Continued)

SUBPROGRAM Goal o Key Events 1984 Performance Milestones	Key Event Timing 1984	1985	1986	After 1986
BUILDINGS, LIGHTING AND SOLAR				
Improve building envelope thermal performance and indoor environmental control systems.				
o Issue report on residential indoor air quality study.			•	
Improve the efficiency and application characteristics of building lighting systems.				
o Issue validated design guidelines for estimating heat contribution of lighting systems.				•
Test and develop improved refrigeration systems for commercial buildings.				
o Issue report on analysis and verification of refrigeration/HVAC/lighting trade-offs in supermarkets.				•
Evaluate and explore advanced solar heating system concepts.				

APPENDIX D

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.

ASHRAE / 1791 Tullie Circle, N.E. / Atlanta, GA 30329

Telephone / 404-636-8400
Telex / ASHRAE 705343

Wm. W. Seaton
Manager of Research

TO: Participants in Building Energy Research Workshop, Airlie House, December 5-7, 1983

FROM: Bill Seaton

DATE: November 4, 1983

SUBJECT: ASHRAE Research Program

Attached is a reprint from the October 1983 ASHRAE JOURNAL which describes the Society's Research Program and the projects currently being sponsored. Also included is a brochure entitled "ASHRAE Research at Work" which outlines the five categories into which the research projects are classified.

Annually, the Society's Board of Directors sets goals for the allocation of research funds into each of these categories. The goals of 1983-84 are:

Energy	25%
Air Quality	20%
Human Response	15%
Applied Science	25%
Equipment	15%

WWS/ss
Encl.

ASHRAE Research 1983-84

WILLIAM W. SEATON
Member ASHRAE
Manager of Research

J. RICHARD WRIGHT, P.E.
Member ASHRAE
Director of Technology

THE Society utilizes all research fund contributions for projects and grants-in-aid during the succeeding year. Approximately 25 percent of the funds are from contributions of $1,000 or above, but the major portion of income is from more modest contributions, indicating strong member support. During Fiscal Year 1982-83, the efforts of the Research Promotion Committee led by Chairman Thomas J. Ferdelman collected $672,751. The budget for projects and grants-in-aid for 1983-84 is $900,000. ASHRAE continues to utilize funds from government agencies and cooperates with other groups to jointly fund Special Projects of mutual benefit. Special Projects include accelerated promulgation of standards, technical publications, and research.

RESEARCH PROJECTS

During Fiscal Year 1982-83 (ending June 30, 1983), ASHRAE initiated twenty new projects and completed thirteen projects. The average cost of new projects was approximately $55,000. Subjects of the new projects ranged from sound control to food quality studies. Fifteen technical papers based on research projects were presented at Society meetings during the year.

ASHRAE research projects result either from work statements initiated by the Society's Technical Committees or Task Groups or from unsolicited proposals submitted by any organization interested in conducting research for ASHRAE. Any research related to ASHRAE's mission of advancing the arts and sciences of heating, ventilation, refrigeration, or air conditioning is eligible for funding.

Work statements originating from technical committees or task groups, after approval by the Research and Technical Committee, are offered to prospective bidders for *proposals*. The bidders' list includes universities and agencies which have a history of cooperative research with ASHRAE or have indicated an interest in ASHRAE research.

Unsolicited proposals are accepted from organizations interested in conducting ASHRAE-related research from self-generated ideas.

Regardless of whether the proposals are solicited from work statements or are unsolicited, the following information should be provided:

1. Precisely what is to be done, by whom, under whose personal supervision, with man hours, materials, instruments and apparatus required, and costs for each.
2. Information regarding the investigator's special expertise, experience, and/or ability which especially qualify him for the research proposed.
3. Identified contribution from his organization's resources for the conduct of the project.

GRANTS-IN-AID

Eight grants-in-aid of up to $5,000 were awarded to graduate students who will be conducting research in a field of interest to ASHRAE during the current year. These students and their institutions are listed below:

1. Ebrahim T. Handy, University of Texas at El Paso
2. Darwin Kiel, University of Alberta
3. John William Hanify, Illinois Institute of Technology
4. Brian J. Kitchen, Wichita State University
5. Mayalu Kulus Nzuzu, University of Illinois
6. Stephen P. Ebner, Catholic University of America
7. Daryl G. Erbs, University of Wisconsin-Madison
8. Kathy A. Riblett, Kansas State University

Applications for grants-in-aid are accepted from faculty advisors to the Manager of Research. The application should state:

1. Student's name, qualifications, his or her need for support, and copy of transcript
2. Significance of proposed research
3. Outline of plan of procedure
4. Approximate budget
5. Extent to which institution will support the work
6. Plans for seeking other funds for this or related work
7. Anticipated plans for publication of research results
8. Faculty advisor's and institution's qualifications

The latest grants brought the totals to $346,532 awarded to 78 students during the 14 years the program has been in effect. Recipients have represented 46 different colleges and universities. The student research programs have resulted in numerous published ASHRAE papers and other reports, mostly theses.

CO-SPONSORED CONFERENCES

ASHRAE co-sponsors conferences in the Society's area of interest, which permits ASHRAE participation on steering committees, encourages member participation, and permits ASHRAE to catalog and distribute all papers resulting from the conferences. The papers are listed in ASHRAE's composite index of technical articles and are available for purchase through the Publication Sales Department.

Co-sponsored Conferences—1982-83

Purdue Compressor Conference
35th Annual Conference on Engineering in Medicine and Biology
Thermal Performance of the Exterior Envelopes of Buildings II
International Daylighting Conference
Fourth International Symposium on the Use of Computers for Environmental Engineering Related to Buildings
Third Seminar of Thermal Insulation for Industrial/Commercial Applications
Second International Congress of Building Energy Management
2nd International Symposium on Legionella

Co-sponsored Conferences—Future (to date)

Solar '83
Workshop on Energy Conservation in Small Office Buildings
Management of Atmosphere in Tightly Enclosed Spaces
Workshop on HVAC Controls Modeling and Simulation
1985 Conference on Civil Engineering Education
Clima 2000
1985 International Symposium on Moisture and Humidity

SPECIAL PROJECTS AND TASKS

ASHRAE Special Projects and Tasks are cooperative ventures which involve cost sharing between the Society and outside organizations, in accordance with the "Policy for Solicitation and Acceptance of ASHRAE Special Projects." During 1982-83 four new Special Projects and Tasks utilizing $47,390 supplied by outside agencies were initiated, four Special Projects and Tasks were completed, and five Special Projects and Tasks initiated in prior years were continued. The fiscal year expenditure for Special Projects and Tasks totaled $477,000, excluding overhead.

After more than ten years as consultant for Special Projects, Presidential Member Frank H. Faust retired as of June 30, 1983. J. Richard Wright, Director of Technology, and staff have assumed full responsibility for soliciting and negotiating Special Project contracts, insuring that traditional Society procedures are preserved. New or pending Special Projects for FY 83-84 include technology transfer of passive solar energy research and a study of infiltration in refrigerated warehouses. It is anticipated that these projects will utilize more than $404,000 supplied by outside agencies and direct expenditures of $367,000 by ASHRAE.

PROJECTS FOR 1983-84

The Board of Directors has approved expenditures for research projects and grants-in-aid totaling $900,000 for FY 83-84. Of the total amount, $698,000 is required for continuing and recently approved projects, leaving $202,000 available for new projects. Competing for the new project funds are 16 proposals and many work statements in various stages of development, plus additional anticipated proposals.

Listed below are projects that will be active during the current fiscal year. Immediately below the title is shown the expected duration of the project, the agency conducting the research, and the sponsor(s) of the research.

221-GRP, HEAT TRANSFER AND PRESSURE DROP IN CONDENSING AND EVAPORATING MULTICOMPONENT FLUIDS

(December 1980-December 1983)
Rensselaer Polytechnic Institute
TC 8.5, Liquid-to-Refrigerant Heat Exchangers

Standard compressor design dictates that oil in some quantity will be present as part of the working fluid in any air-conditioning or refrigeration system. The purpose of this project is to improve the understanding of such multicomponent two-phase flow. Specifically, the effect of a second nonvolatile liquid component on a condensing and evaporating fluid will be investigated.

The program will concentrate in two areas: (1) two-phase flow pattern studies and (2) pressure drop and heat transfer in forced convection horizontal tube flow with condensation or evaporation. Oil-refrigerant mixtures will be used in these studies in view of their common usage in the refrigeration and air-conditioning industry.

224-RP, INVESTIGATION OF THE EFFECT OF OIL ON HEAT TRANSFER AND PRESSURE DROP IN REFRIGERANT EVAPORATORS

(September 1978-October 1983)
Duke University
TC 8.4, Air-to-Refrigerant Heat Transfer Equipment

The heat transfer and pressure drop in the evaporator of a refrigeration system are influenced by the presence of oil in the refrigerant. In general, in the limited amount of work published, investigators have found that the presence of oil in direct expansion evaporators in concentrations as high as 10 percent leads to increases in both true heat transfer coefficient and friction factor, while in flooded systems the heat coefficient decreases when the oil concentration exceeds about three percent. In addition, the presence of oil in refrigerant increases the saturation temperature at a given evaporator pressure—an effect which can be overwhelming at low temperatures and moderate oil concentrations. Thus, the influence on heat transfer, pressure drop, and saturation temperature must all be accounted for to correct for the presence of oil in the evaporator.

The object of this project is to collect experimental data which will permit the determination of pressure drop and "local" heat transfer coefficients for refrigerants evaporating in a multi-pass horizontal tube evaporator when oil is circulated with the refrigerant. A comprehensive review of the published information will be made and examined for application to refrigeration systems. Finally, a generalized calculation procedure for pressure drop and heat transfer coefficients that will account for the effects of the presence of small percentages of oil in a refrigerant evaporator will be developed.

253-RP, CONTROL STRATEGIES FOR MINIMUM ENERGY USE

(January 1980-October 1983)
Duke University
TC 1.4, Control Theory & Application

The purpose of this project is to determine how to coordinate the controllable parameters in an HVAC system to meet the requirements of the system with a minimum of energy use or cost. This need is of relatively recent origin, reflecting the increasing cost of energy, as well as the increasing complexity of environmental control systems. Today, in virtually all building systems, there are numerous control options which, if properly exercised, will lead to minimum energy use. These options are represented by equipment selection, by energy source, by time sequencing, and by the levels of comfort provided to the building occupants. To take advantage of the control option, it is necessary to view the system as a composite of dynamic subsystems, many of which interact. The dynamic aspect of the control process is present in the building structure, the equipment, the distribution networks, the loads, and the comfort requirements. At the present time, controls are applied to take advantage of some of the options suggested, but do not, however, operate on the composite HVAC system.

The project includes composite modeling of a building with a particular HVAC system. This model will reflect the interrelation between comfort, the building structure and the various building HVAC subsystems, components, control systems and energy requirements. The model will provide the minimum energy usage requirements for selected control techniques while maintaining comfort conditions in the building.

268-RP, DEVELOPMENT OF A METHOD TO TEST GASEOUS CONTAMINATION REMOVAL DEVICES

(November 1980-January 1984)
TRC Environmental Consultants, Inc.
TC 2.3, Gaseous Air Contaminants and Gas Contaminant Removal Equipment

With the increasing cost and scarcity of energy required for climate control in occupied spaces, there is an immediate need to reduce ventilation rates for the

purpose of energy conservation. Decreasing ventilation rates cause an increase in the concentration of indoor generated gaseous pollutants and can result in an unhealthy and/or unpleasant environment. One way to alleviate this situation is by recirculation of the air through a removal device. There presently exists no standard method for the evaluation of odor control or gas phase air cleaning devices comparable to ASHRAE Standard 52-76 for particulate air cleaning devices.

The purpose of this study is to establish a consistent, repeatable method for evaluating the performance of gaseous contamination removal devices. This will be accomplished by defining a suitable test duct, by establishing a method of injecting test gases or aerosols, by specifying the sampling and analytical principles to be used, and by establishing odor measurement and odor level reporting methods that relate to equivalent fresh air (EPFA) when odor level is the only valid criteria.

295-RP, FINNED TUBE CONTACT CONDUCTANCE STUDIES
(November 1981-November 1983)
University of Missouri-Rolla
TC 1.3, Heat Transfer and Fluid Flow

All techniques for rating heat exchangers under dry and wet operating conditions include the fin-to-tube contact resistance in the air side thermal resistance. Thus, accurate data and a corresponding correlation are necessary to produce reliable ratings over a wide range of design parameters without unnecessarily high testing costs. The heat exchangers of concern in this project are commonly called extended-surface coils or simply fin coils. In fin coils, the external surface of the tubes is known as primary, and the fin surface is called secondary.

The objective of this project is to experimentally evaluate the contact resistance between the primary and secondary surfaces of finned tubes and to correlate the results, using appropriate theory or dimensional analysis, in terms of reproducible and defined parameters such as net contact interference or resultant pressure to bond the fins.

298-RP, ANALYSIS OF OPEN SORPTION AND REFRIGERATION HUMIDITY CONTROL SYSTEMS
(March 1983-March 1985)
Kansas State University
TC 3.5, Sorption

Conditioned air is air having specified properties of cleanliness, temperature, and humidity, and its production often requires dehumidification. This may be accomplished using mechanical refrigeration systems or sorption with aftercooling from natural sources. The choice of dehumidification method or methods is usually based on the specified discharge condition, a specified design condition and the available sources of energy types. Dehumidification equipment will operate for the majority of the time under conditions much less severe than those used for design purposes. However, there presently exists no systematic procedure for determining the optimum system for routine, day-to-day operation, regardless of whatever principle is used.

The objective of this project is to develop an analytical method for estimating the annual energy consumption and for determining the cost-effectiveness of alternative humidity-control systems, including refrigeration, open-sorption dehumidification, and combinations of refrigeration and open-sortion dehumidification. This will result in a procedure which may be used to determine the optimum dehumidification system. Design conditions, climate data, equipment costs, operating costs, and the availability and cost of energy will be inputs to the procedure.

308-RP, INVESTIGATION OF DUCT LEAKAGE
(April 1982-April 1984)
ETL Testing Laboratories, Inc.
TC 5.2, Duct Design

This project is designed to generate engineering data on leakage rates from the various types of longitudinal seams and transverse joints commonly used in low velocity heating, ventilating and air conditioning duct construction. Of particular interest is the assignment of relative leakage rates (as a function of pressure) between longitudinal seams, the corners of transverse joints, and the transverse sections of the joints, for the various types of joints tested. Such data will be useful in predicting leakage in duct systems, evaluating methods of reducing leakage to meet predetermined levels, and providing engineering support for present and future duct construction standards. The various types of ducts being tested include rectangular sheet metal, fibrous glass, spiral-wire-reinforced flexible, and round sheet metal.

This project is being co-sponsored by the Thermal Insulation Manufacturers Association and the Sheet Metal and Air Conditioning Contractors' National Association.

309-RP, DYNAMIC AND SEASONAL PERFORMANCE OF CENTRAL FORCED-WARM-AIR HEATING SYSTEMS INSTALLED IN RESIDENCES
(June 1982-September 1984)
Battelle Columbus Laboratories
TC 6.3, Central Forced Air Heating and Cooling Systems

The objectives of this project are twofold. The first objective is to provide a basis for making refinements to the NBS, DOE and ASHRAE test procedures and consensus standards for evaluating seasonal operating efficiency and for the evaluation of energy savings attributable to different central forced-warm-air heating equipment under a wide variety of application conditions. The second objective is to assist industry by providing information in the ASHRAE *Handbook* in the areas of (a) computation of seasonal system performance for residential forced-warm-air heating systems as a function of significant variables, (b) the selection of appropriate forced-warm-air heating equipment and components for specific applications to achieve energy conserving and cost-effective system design, (c) the sizing of equipment and components for optimum system operating performance and energy use, and (d) the installation and operation of forced-warm-air heating systems for optimized energy savings.

This project is being jointly funded by the Brookhaven National Laboratories (DOE), the Gas Research Institute, and ASHRAE.

315-RP, A STUDY TO EVALUATE ENERGY EFFICIENCY OF ATRIUMS
(October 1983-October 1984)
W.S. Fleming & Associates, Inc.
TC 9.8, Large Building Air Conditioning Applications

The use of atriums in new building construction is very prevalent today. Building developers and owners are being persuaded that atriums are aesthetically pleasing, provide a good environment, and are energy efficient. However, it is the current consensus of the building design industry that more accurate and relevant data are necessary for the proper energy efficient design of atriums and the air conditioning system serving them.

The objective of this project is to collect accurate and relevant data on both atriums and the air conditioning systems serving them. The data shall include, but not be limited to, existing atrium construction, energy usage, and description of the air conditioning systems serving them. Modeled energy efficient atriums developed from the existing atriums through computer modeling, and energy usage comparisons of the existing and modeled atriums with those of the building type in which the atriums were found will be studied. A comprehensive literature analysis shall be employed for the data collection.

318-RP, LOW FREQUENCY NOISE RADIATION FROM AIR CONDITIONING DUCTS
(September 1981-September 1983)
University of Missouri-Rolla
TC 2.6, Sound and Vibration Control

Low frequency noise radiation, or "rumble", from air conditioning ductwork continues to be a problem despite the use of dissipative duct mufflers and external wall lagging. There is virtually no quantitative work reported on aerodynamically excited rumble and there appears to be no existing methods for estimating rumble levels or for assessing the relative roles of acoustic and aerodynamic excitation.

The experimental tests to be conducted will entail the measurement of acoustic transmission loss in duct walls both in the laboratory and in the field. Round and rectangular ducts, both with and without external lagging, will be tested. These results will be compared to Cummings theoretical calculations.

321-RP, HVAC SYSTEM DYNAMICS AND ENERGY USE IN AN EXISTING BUILDING
(August 1982-February 1984)
University of Wisconsin
Task Group on Dynamic Response

The purpose of this research project is to determine strategies which incorporate building occupant comfort and HVAC system dynamics and interactions which will potentially reduce energy use. These strategies will then be implemented and tested. The strategy development is based on the analysis of data on systems performance presently available or being taken during the execution of the project.

First a TRNSYS model of the Atlanta IBM building's HVAC system and control system will be developed. Next the model will be used to evaluate current and proposed control strategies and to compare the results of the model prediction with actual results. Finally, the control strategies for energy and economic savings will be evaluated.

322-RP, DEVELOPMENT OF ALGORITHMS FOR SIMULATING THE PERFORMANCE OF COOLING TOWERS AND EVAPORATIVE CONDENSERS
(June 1982-October 1983)
Pennsylvania State University
TC 8.6, Cooling Towers and Evaporative Condensers

With the increased use of cooling towers as a direct source of chilled water and with the advent of so-called "free" cooling refrigeration cycles, a more refined cooling tower model than that which is described in the current ASHRAE publications is needed.

This research involves development of algorithms to simulate wet cooling towers, evaporative condensers and evaporative liquid coolers. Algorithms that can be used to design this equipment and to compute the energy consumption will be developed. The validity of these algorithms will be simulated by at least one unit from each of the three equipment types. The results will be compared to existing equipment for which operating data exist.

These algorithms will become part of a revised ASHRAE publication on the subject of the simulation of HVAC components and systems for energy calculations.

332-RP, ENERGY SAVINGS THROUGH NATURAL DAYLIGHTING—EVALUATION OF TECHNIQUE
(June 1982-September 1983)
Ross & Baruzzini, Inc.
TC 4.5, Fenestration

A previous research project 258-RP, Energy Savings Through Natural Daylighting, provided a simplified methodology based on "first principles." The object of this follow-on project is to evaluate this method for accuracy, reliability, and practicality and to use the results to modify the recommended procedure if required.

The evaluation consists of comparing the algorithm results with DOE-2 and with case studies made at NBS, the University of Pittsburgh and IBM. A review of the state of the art in daylight prediction techniques is being made and compared to the results obtained by use of the algorithm. Testing of individual rooms is also being done, as is the monitoring of energy use instrumentation in buildings with daylighting controls.

336-RP, INFLUENCE OF OIL ON PRESSURE DROP IN REFRIGERANT LINES
(September 1983-March 1985)
University of Missouri-Rolla
TC 10.3, Refrigerant Piping

ASHRAE research project 109-RP as originally funded was to include R502 refrigerant and alkylbenzene lubricants in the experimental work. Due to overruns, the project was closed without testing either R502 or alkylbenzene. Subsequently, a study of suction line pressure drop in an R502 operating system using both a 150 SUS mineral oil (that used in 109-RP testing) and a 150 SUS alkylbenzene oil was made by others with less than satisfactory results.

It is believed that, in order to provide the refrigeration industry with reliable handbook pressure drop data, the pressure drop tests covered by 109-RP should be conducted with other types of oil and R502.

The object of this work is to extend the research conducted under 109-RP, Transport of Oil in Pipes by Refrigerant Vapor, to include the influence of oil/refrigerant solubility on pressure drop and on experimental verification that these correlations apply to R502 refrigerant.

337-RP, MEASUREMENT OF WATER VAPOR MIGRATION AND MOISTURE STORAGE IN COMPOSITE BUILDING CONSTRUCTIONS
(March 1983-September 1984)
The Manville Corporation
TC 4.4, Thermal Insulation and Moisture Retarders
TC 9.6, Systems Energy Utilization

The investigation of moisture behavior in building envelope components has much practical importance since it is the condensation or wetting phenomenon that is believed to cause a significant deterioration in the thermal performance of wall insulation. In addition, the presence of liquid water is known to cause physical deterioration of the structure by causing decay, corrosion, and paint failure.

The primary objective of this research project is the development of reliable fundamental data under carefully controlled laboratory conditions on the accumulation of condensed water vapor in a typical insulated light-frame wood residential wall, and the effect of that moisture on thermal performance of the wall. This information is needed for inclusion in the 1985 ASHRAE Handbook of Fundamentals.

A secondary objective of this project is the development of basic moisture migration data for validation of theoretical models for moisture vapor transfer as applied to a composite residential wall structure.

341-RP, THERMAL CONDUCTIVITY OF LOW AND INTERMEDIATE MOISTURE FOODS
(December 1982-December 1984)
Texas A & M University
TC 11.9, Thermal Properties of Foods

Prior to this time, most thermal conductivity work has been done on foods having high moisture content, where water has a predominant influence. This research will advance the state of the art in engineering systems for low and intermediate moisture foods.

The objective of this project is to measure the thermal conductivity of low and intermediate moisture foods such as jams, jellies, and pie filings; sausage and other comminuted meat products; dried fruits, bakery products and pet foods.

Some of the factors to be considered are mass density, moisture content and porosity. This work will set the stage for the future development of mathematical models for the prediction of thermal conductivity of similar foods.

342-RP, A STUDY AND REVIEW OF EXISTING DATA TO DEVELOP A STANDARD METHODOLOGY FOR RESIDENTIAL HEATING AND COOLING LOAD CALCULATIONS
(September 1982-February 1984)
Oklahoma State University
TC 4.1, Load Calculation Data and Procedures

The present manual methods of residential heating and cooling load calculations are oversimplified and have remained essentially unchanged for 30 years. Very sophisticated mainframe computer simulation programs are available, but these are too complex and expensive to be practical for single family residential work.

This project will develop a summary of accurate and relevant load calculation data which will be used to prepare an accepted accurate method of calculating heating and cooling loads in single and multi-family residential buildings. In addition, such factors as air quality, underground housing, mobile homes, and the use of hand-held calculators and microcomputers will be considered.

344-RP, A STANDARD DEVICE FOR CALIBRATING CALORIMETER TEST ROOMS
(September 1982-September 1984)
Kansas State University
TC 7.5, Room Air Conditioners and Dehumidifiers

An industry-wide standard for calibrating room air conditioner calorimeter rooms does not exist. At present, the only way a manufacturer can check the accuracy of a calorimeter room is by checking his instrumentation against the cooling capacity of a calibrated "standard air conditioner." Once calibrated, this par-

ticular air conditioner is used as a secondary standard by the manufacturer. Consequently, if for any reason this "standard air conditioner" becomes damaged in transport, loses charge, or in any way drifts from calibration, the manufacturer may be led to believe his calorimeter room instrumentation has drifted.

The objective of this research project is to develop an accurate calibration system which can be duplicated by individual room air conditioner manufacturers for calibrating calorimeter test rooms. This will include the design, construction, and demonstration of a working device capable of providing a "standard cooling capacity" that can be measured accurately enough at a manufacturer's location to be considered a secondary standard.

This project will cover all phases of the development of a "standard cooling capacity" device, including the development of all the necessary sub-systems to achieve an accurate calibration of a calorimeter test room.

350-RP, EFFECT OF PROCESSING, PACKAGING AND STORAGE ON HIGH-QUALITY SHELF LIFE OF HOT-BONED GROUND BEEF
(September 1982-September 1985)
University of Maryland
TC 11.1, Meat, Fish and Poultry Products

Since the energy crisis of 1974, attention has been directed toward the opportunity of energy-saving methods without serious quality losses during refrigerated and frozen handling and storage of foods. Studies conducted have demonstrated that savings of 20-40 percent in energy consumption can be achieved with only trivial losses in storage-duration and/or quality level of frozen fruits, vegetables, and a variety of prepared foods. It was also established that substitution of plant proteins (such as textured vegetable proteins) for animal protein, did not adversely affect quality or shelf life of the prepared food.

Low temperature handling of red meat is also undergoing substantial changes so that similar information needs to be developed. Approximately 70 percent of fresh beef, for example, is now distributed as boxed primal cuts or boned, diced, or ground beef.

This research project will determine the effects of chilling and freezing rates, packaging, and storage conditions on high-quality storage life of chilled and frozen packaged hot-boned beef.

Based on this information, the cost/benefits for optimal energy utilization for the desired high-quality shelf life of beef will be calculated.

353-RP, A STUDY TO DETERMINE SUBJECTIVE HUMAN RESPONSE TO LOW LEVEL AIR CURRENTS AND ASYMMETRIC RADIATION AT THE LOWER BOUNDARY OF HUMAN COMFORT
(December 1982-December 1983)
John B. Pierce Foundation Laboratories
TC 2.1, Physiology and Human Environment

Thermal non-uniformities such as drafts, radiant asymmetry and vertical temperature differences in an otherwise thermally comfortable space may cause local discomfort that detracts from the environment.

The objective of this study is to obtain sufficient data on the response of human subjects to drafts and radiant asymmetry on the cold side of the comfort range in order to establish guides on acceptability in that environment. The study will include both men and women under 40 years of age and a comprehensive literature analysis of recent investigations of responses to low level air currents and radiant asymmetry.

354-RP, A STUDY TO DETERMINE A REPLACEMENT FOR THE DUST SPOT TEST METHOD OF DETERMINING AIR FILTER EFFICIENCY
(April 1983-April 1984)
University of Minnesota
TC 2.4, Particulate Air Contaminants and Particulate Contaminant Removal Equipment

Although one of the most widely used methods of testing air filters is the ASHRAE dust spot test method, (ASHRAE Standard 52-76), it has certain shortcomings. Chief among these is the tedious and time consuming nature of the tests.

The objective of this research is to study a new filter efficiency measurement method based on the use of laser optical counters as a possible replacement for the dust spot test method. The first step will include a comprehensive survey of the literature on the response characteristics of laser optical particle counters so as to prevent duplication of research.

The second task is to develop a new test method based on laser counters and reduce it to practice. Finally a series of air filters with efficiencies of 20% to 98% will be tested using the new method to determine the sensitivity and reproducibility of the new method.

359-RP, UPDATING COOLING LOAD TEMPERATURE DIFFERENCES AND COOLING LOAD FACTORS FOR CHAPTER 25 OF THE HANDBOOK OF FUNDAMENTALS
(March 1983-March 1984)
Ayres Sowell Associates
TC 4.1, Load Calculation Data and Procedures

The current methodology recommended by ASHRAE for design cooling load calculations is set forth in the 1981 Handbook of Fundamentals (HOF). With this methodology, cooling load transmission components at each hour are calculated directly by multiplying wall, roof and glass UA values by Cooling Load Temperature Differences (CLTD's). Similarly, glass solar and internal load components are found by multiplying heat entering the space from these sources by cooling load factors (CLF's).

The validity of the CLTD/CLF method rests upon the accuracy of tables of these parameters presented in HOF. Since their development in 1974-75 a number of improvements have been made in the fundamental data used in the determination of the CLTD's and CLF's.

The objective of this work is to update the CLTD/CLF tables in the Handbook of Fundamentals. Specifically, it is intended to recalculate the room weighting factors, exploring the effects of a range of parameters, and recalculate the CLTD/CLF's presently reported in the Handbook. The dependencies of the CLTD/CLF's on building properties will also be reevaluated. If indicated by the results, the set of CLTD/CLF's reported in the Handbook will be expanded to reflect important, new dependencies such as night and weekend shut-down.

362-RP, A STUDY TO DETERMINE A METHOD OF PREDICTING ENERGY LOSSES DUE TO INFILTRATION IN REFRIGERATED WAREHOUSES
(April 1983-October 1983)
Georgia Institute of Technology
TC 10.5, Refrigerated Distribution and Storage Facilities

In recent years the size and number of refrigerated distribution and storage facilities have grown significantly, and it is now estimated that refrigerated warehouses use 1×10^{14} Btu's of energy per year.

Although infiltration represents 50% or more of this refrigeration load, the method of calculation for this load is fundamentally left to the experience of the design engineer. This implies a tendency to over design or, even worse, can result in an insufficient refrigeration capacity.

The objective of this project is to develop means of accurately predicting the loss of refrigeration energy due to infiltration through doorways and other leakage sources in refrigerated warehouses. Both a comprehensive literature analysis and field testing will be employed. This will lead to development of mathematical formulations and a computer algorithm to quantify the infiltration losses. Ultimately these will be reduced to a series of tables, figures or nomographs for use by design and plant engineers for load calculation and energy analyses. The parameters to be examined shall include the temperatures of the refrigerated and adjacent spaces; the volume and ceiling height of the refrigerated space; size, type, and number of doorways; the effect of peripheral devices such as air curtains, strip curtains, and bumper doors; the effect of enclosed, refrigerated loading docks; and wall and ceiling leaks.

This project is being partially funded by The Refrigeration Research Foundation.

363-RP, UPGRADING THE DOCUMENTATION OF THE PROPOSED TC 4.7 SIMPLIFIED ENERGY ANALYSIS PROCEDURE
(April 1983-October 1983)
Control Data Corporation
TC 4.7, Energy Calculations

At present, HVAC engineers have limited

options in the tools available for performing energy analyses on new and existing buildings. Manual methods are not sufficiently accurate or inclusive for use on commercial buildings, while comprehensive computerized procedures cannot be usually justified for small and medium sized buildings. Consequently, there has been a growing demand for the development of a simplified energy analysis procedure that can be used manually, as programmed into micro-computers.

In response to this demand, TC 4.7, Energy Calculations, has developed and documented a modified bin method which is an improved version of the Carrier REAP procedure and includes the ASHRAE cooling load factors and part load performance of heating/cooling equipment. The procedure has been tentatively called the proposed TC 4.7 simplified procedure.

Over the past few years, several studies have shown that the simplified procedure provides results that compare well with the comprehensive computerized energy analysis procedures.

The purpose of this research is to provide additional HVAC system and equipment examples and prepare a camera-ready copy of the documentation, in preparation for a full release of the procedure to the public.

364-RP, PREPARING 29 ADDITIONAL WEATHER DATA SETS PLUS SOLAR DATA IN WYEC FORMAT
(June 1982-September 1983)
Loren W. Crow Consultants, Inc.
TC 4.2, Weather Data

During 1978 and 1979, the Society sponsored project 239-RP which developed and documented in tape format the hourly weather data that were representative of long term climatic means for 22 cities across the country. This work has been invaluable for use as a standard in making energy calculations.

The same investigator will, in this project, collect and document similar data for an additional 29 stations. This increase in coverage will permit the development of interpolated iso-lines of various climatic factors.

The results of this study will be available for purchase on microfiche pages or on magnetic tapes.

366-RP, DEVELOPMENT AND PREPARATION OF A DESIGN DATA MANUAL FOR CLOSED-LOOP GROUND-COUPLED HEAT PUMPS
(April 1983-May 1984)
Oklahoma State University
TC 6.9, Thermal Storage

In areas of 3,000 heating degree days or less, the use of ground-coupled heat pumps appears to be a cost-effective heating/cooling method open to large numbers of existing buildings, particularly residences. In cooling, the condenser heat is put back into the ground which greatly improves air conditioning C.O.P.'s and reduces peak demand utility loads. The sales appeal of putting heat back into the ground in summer for use in fall or winter, eliminating the need for a back-up system, and eliminating the unattractive appearance of solar roofs indicates that this product will grow rapidly when made available to the public.

The purpose of this project is to collect and organize data pertinent to design of the ground coupling device from available literature and active projects. It will take into account thermal properties of different soils over a range of moisture levels, pipe depths and spacings, surface water, horizontal and vertical loop alignments, direction of heat flow, heating/cooling load ratio, and climatic variations.

A manual providing data for design of closed-loop, ground-coupled heat pump systems, using the results obtained will be prepared, and additional data needed for the design of these systems will be identified.

370-RP, TRANSPIRATION COEFFICIENTS OF FRUITS AND VEGETABLES IN REFRIGERATED STORAGE
(January 1984-January 1987)
University of Florida
TC 11.5, Fruits, Vegetables and Other Products

The rate of transpiration in fruits and vegetables is one of the main factors that affect quality of the product. Moisture transpires continuously from fruits and vegetables during handling and storage when subjected to a water vapor pressure deficit. Under many conditions, the loss may be great enough to cause the commodity to shrivel, impair the flavor and lower the market quality. The resulting loss in weight not only affects appearance, texture, and flavor but also reduces the salable weight.

The objective of the proposed research is to obtain a body of relevant and accurate data on the transpiration coefficients of fruits and vegetables in order to permit the determination of moisture loss rates of these products during cooling or storage at various levels of temperature and humidity. This work will be carried out in two phases. Phase I will concentrate on the development and demonstration of a satisfactory method for measurement of transpiration coefficients, and Phase II will be devoted to the actual measurement of the coefficients. Coefficients will be measured on a number of products including grapefruit, grapes, lemons, limes, oranges, peaches, strawberries, blueberries, lima beans, snap beans, beets, cabbage, carrots, onions (dry), peppers and tomatoes.

378-RP, AN EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF REFRIGERANT—OIL MIXTURE ON CONDENSATION HEAT TRANSFER COEFFICIENT AND PRESSURE DROP IN WATER—COOLED SHELL AND TUBE CONDENSERS
(December 1982-December 1984)
Concordia University
TC 1.3, Heat Transfer and Fluid Flow

Migration of lubrication oil from the crank case of a compressor into the other components of a refrigeration system is a problem which has a significant effect on the heat transfer from and to the circulating refrigerant. The presence of oil in the refrigerant condensate on the condenser tubes results in variation of thermal properties in comparison with that for pure oil or refrigerant.

The objective of this research is to investigate the mechanism of heat transfer during the condensation of halogenated hydrocarbon refrigerant when mixed with a predetermined amount of a selected lubricant oil using experimental studies.

In this study, the specific effects of oil-refrigerant solutions on the heat transfer and pressure drop in a water-cooled shell and tube condenser will be investigated. Correlations of both condensation heat transfer and pressure drop in the condenser for one completely miscible and two other partially miscible refrigerant-oil mixtures will be developed. These will serve as tools for modifying the design method of the water-cooled refrigerant condenser taking into account the effects of oil.

379-RP, ARI-JOINT PROJECT ON HEAT PUMP STANDARDS
(July 1982-July 1983)
Air Conditioning and Refrigeration Institute and ETL Testing Laboratories
TC 7.6, Unitary Air Conditioners and Heat Pumps

The air conditioning industry, through ARI and its on-going certification program for unitary air-conditioners, has initiated a continuous air flow test verification program using a draft of the Society's Standard 116P. The scope of the program includes sixty unitary air conditioners of various types and sizes including many operating variations.

This project will verify the applicability of the proposed Continuous Indoor Air Flow Procedure using standard production equipment and will test fifteen unitary heat pumps of various sizes and types covered by the scope of proposed Standard 116P.

382-RP, DEVELOPMENT OF HVAC EQUIPMENT COST DATA BASES
(October 1983-April 1985)
ADM Associates, Inc.
TC 1.8, Owning and Operating Costs

Recently, ASHRAE sponsored a research project 310-RP, "Establish Feasibility and Background for an Equipment Maintenance Costs Work Statement" which established that sufficient sources do exist which contain heating, ventilating and air-conditioning (HVAC) equipment maintenance cost data (MCD). The need for these data in establishing objective evaluations of alternative systems over the life of the system and/or its components is evidenced by numerous inquiries received regarding this information during the past several years.

The results from 310-RP indicate that many manufacturers, building owners and operators, and consulting engineers are interested and anxious to lo-

cate sources of HVAC equipment maintenance costs and that there are many sources in the United States which have available HVAC equipment maintenance cost data in various formats.

The objective of this project is to obtain accurate and relevant data on HVAC equipment/system MCD. The data will be dollars reported spent for HVAC system maintenance for office buildings. This body of data will include buildings where the effects of the type of the HVAC system (reheat, induction, variable air volume, etc.), chiller size, building size, (square feet), location and building usage can be identified. A comprehensive analysis of the data will also be performed in order to determine the most reliable format of presentation.

384-RP, VALIDATION OF VARIABLE-BASE DEGREE-DAY METHOD
(June 1983-June 1984)
University of Colorado
TC 4.7, Energy Calculations

One of the simplest and most widely used methods of estimating energy use for heating and cooling in houses is the degree-day method. The recently developed variable-base degree-day method is the same in principal as the standard degree-day measure calculated for a base temperature specific to a building.

The objective of this project is to ascertain the accuracy of the variable-base method in determining the annual heating and cooling energy use as a basis for comparison. Building data suitable for the validation study will be identified and assembled. In a similar manner, weather data suitable for the validation will be identified. These data will use the variable base degree day to calculate the energy use for heating and cooling for the period for which the energy data are available. Finally the calculated energy use will be compared to the actual energy used to determine the accuracy of the method.

385-RP, DEVELOPMENT OF BIN WEATHER DATA FOR SIMPLIFIED ENERGY CALCULATIONS AND ALGORITHMS FOR GENERATING VARIABLE-BASE DEGREE-DAY INFORMATION
(June 1983-November 1983)
Texas A & M University
TC 4.7, Energy Calculations

The recently developed ASHRAE TC 4.7 Simplified Energy Calculation Procedure requires the use of weather data in the form of "bin" tables where the average number of hours at a certain temperature range or "bin" occurs in each month of the year at selected locations. The existing weather data, however, have several disadvantages such as the absence of solar data and the absence of wet bulb temperature with coincident dry bulb data. Additionally more daily time periods are needed and data are needed based on the "typical weather year" rather than historic averages. Finally all of the weather data need to be available in a format suitable for use on microcomputers as well as larger computers.

The objective of this research project is to develop a more refined grid of dry-bulb and wet-bulb temperature bin data with accompanying solar data than that which is currently available. The purpose of these bin data is for input to newly developed methodologies for simplified energy calculations and algorithms for generating variable base degree day information. The project will develop these data in camera ready form and in tape format for the 50 WYEC cities supplied by ASHRAE.

391-RP, UPDATE INTERNAL LOAD TABLES IN HANDBOOK
(September 1983-May 1984)
ADM Associates, Inc.
TC 4.1, Load Calculation Data and Procedures

Information available on internal heat gain from equipment has not kept pace with widespread use of electronic equipment such as word processors and microcomputers. This makes it necessary to update the load tables in the Handbook of Fundamentals.

A forum on Internal Heat Gains held in 1981 revealed that the available data individually accumulated from a variety of sources were incomplete and difficult to locate. Concern was expressed that the lack of a single, reliable source of equipment data would cause engineers to assume conservative values which would perpetuate over-design of HVAC systems.

Unsuccessful efforts to compile these data over the past several years have led to the conclusion that accumulating and summarizing these data cannot be accomplished on a volunteer basis.

The objective of this project is to obtain equipment load tables which summarize the types of equipment and the range of heat output which can be anticipated in the work environment in 1985. It will include a literature search to summarize appropriate available data on internal heat gain from equipment and a detailed list of equipment found in the work environment with sensible and latent heat output in Btu/hr and watts/hr. Equipment types shall include office equipment such as word processors, copiers, check processors, microfiche readers, CRT terminals, etc.; hospital equipment such as sterilizers, X-ray machines, laboratory equipment; and kitchen equipment of various types.

397-RP, THE EFFECT OF INDOOR RELATIVE HUMIDITY ON SURVIVAL OF AIRBORNE MICROORGANISMS AND THE RELATED ABSENTEEISM IN SCHOOLS AND HOSPITALS
(April 1983-July 1984)
University of Saskatchewan
TC 2.1, Physiology and Human Environment

Tests by several different investigators with comparable human test subjects have shown a reduction in either absenteeism or occurrences of the common cold in seventy-five percent of the studies when the indoor relative humidity was increased during the winter heating season. It has not been possible to establish the cause of the reduction or explain the conflicting results in the remaining tests. Laboratory studies of airborne microorganisms show that their survival time in general is minimal in the 40 to 60 rh range.

The objectives of the project are (1) to test the hypothesis that increasing or decreasing the indoor humidity in winter towards 50% in cold climates reduces the survival of airborne microorganisms in buildings and (2) to relate the findings to the absentee rates in 12 schools and 3 hospitals. The studies will continue through the other seasons of the year to create a comparison between absenteeism and survival or airborne organisms in air-conditioned and non air-conditioned buildings.

407-RP, REFRIGERANT PROPERTY TABLES (I-P Units)
(July 1983-November 1984)
University of Idaho
TC 3.1, Refrigerants and Brines

In an earlier ASHRAE project, the thermodynamic property tables and pressure-enthalpy graphs in SI units were prepared for thirty-one commonly used refrigerants. Subsequently, the decision was made to publish the Handbook of Fundamentals in both IP units and SI units. Therefore, there is a need for the same thermodynamic property tables and pressure enthalpy graphs in IP units as well.

This project will prepare these tables and graphs in IP units for use in the 1985 Handbook of Fundamentals.

418-RP, EVALUATION OF SIZING METHODS FOR STEAM CONDENSATE SYSTEMS
(September 1983-April 1984)
University of Missouri-Rolla
TC 6.1, Hot Water and Steam Heating Equipment and Systems

Discussions have taken place at numerous ASHRAE meetings regarding the differences in condensate pipe sizing methods using wet-open, wet-closed, dry-open, and dry-closed techniques and what various manufacturers of steam equipment might recommend. It is not generally agreed as to what techniques apply specifically to the common HVAC steam systems. Before the appropriate techniques can be included in the ASHRAE Handbook of Fundamentals the differences in these techniques or procedures need to be resolved.

The objective of this project is to determine the existing techniques which are used for sizing condensate return lines and compare their results with those developed in ASHRAE research project 167-RP. The differences in the results from the various techniques for a variety of situations will be noted and related to actual HVAC systems. In addition, a simple procedure for sizing steam condensate lines will be recommended for inclusion in the ASHRAE Handbook of Fundamentals.

411-RP, A COMPREHENSIVE DATA BASE FOR ESTIMATING CLOTHING INSULATION
(October 1983-October 1984)
Kansas State University
TC 2.1, Physiology and Human Environment

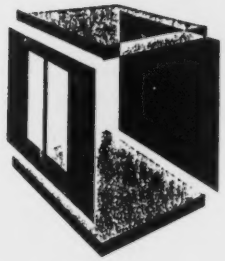
The amount of clothing insulation, expressed in terms of a clo unit, and its distribution over the body directly affect convective, conductive and radiant heat loss from the skin to the environment. ASHRAE Standard 55-1981 is designed so that users can describe the types of garments that people are wearing in a given environment and estimate the levels of clothing insulation.

The purpose of this study is to expand the current data base of garment insulation (clo) values and revise the methods for use in estimating clothing insulation in the standard. Data from this study will be used to develop a new chart of garment insulation values for use in revising ASHRAE Standard 55-1981 and Chapter 8 of the Handbook of Fundamentals as well as to develop new methods for estimating clothing insulation.

421-RP, THERMAL COMFORT OF THE ELDERLY: EFFECTS OF INDOOR MICROCLIMATE, CLOTHING, ACTIVITY LEVEL AND SOCIOECONOMICS
(October 1983-October 1984)
State University College at Buffalo
McMaster University
TC 2.1, Physiology and Human Environment

Information has indicated that during the past two winters many elderly have not maintained the level of thermal comfort in their homes that would be predicted. The combination of their poor thermoregulatory responses, blunted perception of temperature change, and the high cost of heating fuels has resulted in an apparent breakdown in the ability of many elderly to maintain proper thermal comfort. Hypothermia then represents an increased threat to the life of older people.

The objective of this study is to conduct a survey to determine the effects of indoor microclimate, clothing and activity level on the thermal comfort of elderly persons of different socioeconomic groups. By conducting the survey in a large number of homes chosen to represent different socioeconomic groups, the findings can be related to socioeconomic findings and differences in lifestyles.



Applied Science

Projects included in this category are those which lead to a better understanding of the fundamental physical laws and principles which govern the application of heating, refrigerating, ventilating and air-conditioning systems and equipment. The development of the relationships between dry-bulb, wet-bulb, and dew point temperatures, and the new ASHRAE psychrometric charts, which graphically portray this relationship, are examples of applied knowledge of great value to the environmental industry.

Included in this category are such basic studies as heat transfer of water and refrigerants in piping and coils; noise reduction in ducts; principles of heat exchange; heat transfer and pressure drop in condensing and evaporating multi-component fluids; transport of oil in pipes in refrigerant vapor; measurement and analysis of particle size in a gas stream; development of a degree-day method for simplified energy analysis; heat/mass transfer at heat exchange surfaces; and metrication of refrigerant properties.

The results of research projects in this category, in many cases, will not have a direct application to equipment or system design, but will form a basis from which systems and/or equipment having improved performance, reliability or serviceability can be developed or evaluated.

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Equipment

Since its inception, ASHRAE research has been directed, not to the development of products, but to understanding of principles that can be applied for the general good. Since such research is basic, seldom if ever can the benefits be accurately predicted. Accordingly, ASHRAE selection of research projects is not based upon pre-conception of resultant benefits. Research is conducted because some of the Society's most knowledgeable engineers agree that a need exists for information not otherwise available; or if available, it is information too obsolete to be trusted.

Recent projects of this category include propeller fan dynamics; condensible gases in effluents; simulation of flows and temperature in central chilled water systems; development of design data and test procedures for fume hoods; systems effect on fan performance; and, related to energy use, a a survey of the life and maintenance cost of equipment. A better understanding of the mechanical design and operation of heating, refrigerating, ventilating and air-conditioning systems and equipment is the major objective of equipment research.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

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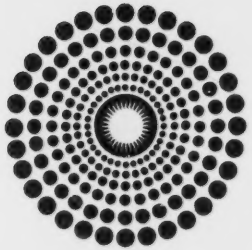

Energy

ASHRAE research concerning thermal characteristics of building materials and efficient operation of systems and components preceded the energy crisis by at least 50 years. Studies to measure and verify energy consumption in existing buildings were funded by ASHRAE beginning in 1967. Studies on passive solar devices date back to 1941.

When the price of oil began its rapid escalation in 1973, ASHRAE's previous work in up-dating technology and documenting the experience of its members allowed the Society to begin development of standards to reduce energy consumption in new and existing buildings.

Recent ASHRAE energy research projects include studies of seasonal heating and cooling; control strategies for minimum energy use; energy savings through use of daylighting; interchangeability of alcohols in appliances designed for fuel oil; development of improved cooling load calculations; and studies in solar energy culminating in several publications. These are examples of how ASHRAE has been providing solutions for energy conservation for many years.

Air Quality

The quality of the air we breathe, both indoors and outdoors, has only recently been of concern to the public, but it has been a concern of ASHRAE for many years.

Fear of the spread of communicable diseases during World War I led ASHRAE's first technical committee to study the problems of adequate ventilation rates in hospitals. This work has continued through the years with ASHRAE taking the leading role in establishing standards for indoor air quality and odor investigation. ASHRAE research activities include development of a test method for tobacco smoke odor control; gaseous contamination removal devices; recommended minimum exhaust air rates for minimizing energy consumption in hospitals; and air pollution studies for residential and commercial heating systems. Special committees have studied the possible role of air- conditioning systems in the spread of Legionnaires' disease and the possibility of ozone depletion by chlorofluorocarbons.

Human Response

Individual response to temperature, humidity, air movement and other environmental factors such as radiant effects of the sun and annoying sound is a major category of ASHRAE research. The response of the individual to surroundings in the home, office, schoolroom and factory has accounted for considerable expenditure of ASHRAE research funds.

With the recent concern for energy requirements to produce comfort, ASHRAE research has been directed to evaluating the relationship between the various comfort parameters and the energy required to maintain comfort. Projects in this category include studies of thermal requirements for human comfort; effect of thermal environment on production and learning; indoor sound criteria for air-conditioning systems; the effect of garment design and fabric on the thermal insulation values of clothing; and application of acceptable temperature drifts to built environments as a mode of energy conservation. Providing at least minimum comfort, well being, health and productivity in the face of critical energy supplies is a major challenge facing ASHRAE in the years ahead.